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Chikamoto

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(54) **INKJET HEAD, FILTER PLATE FOR INKJET HEAD, AND METHOD OF MANUFACTURING FILTER PLATE**

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(51) **Int. Cl.**
B41J 2/175 (2006.01)

(52) **U.S. Cl.** **347/93**

(58) **Field of Classification Search** .... None
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,204,690 A 4/1993 Lorenze, Jr. et al.
5,489,930 A 2/1996 Anderson
5,610,645 A * 3/1997 Moore et al. 347/93
5,850,241 A 12/1998 Silverbrook
6,086,195 A 7/2000 Bohorquez et al.
6,685,299 B2 2/2004 Hirota
7,047,642 B2 5/2006 Kataoka et al.

FOREIGN PATENT DOCUMENTS

EP 1 236 573 A2 9/2002
EP 1 336 486 A2 8/2003
JP 6-255101 A 9/1994
JP 2000-296613 A 10/2000
JP 2002-355962 A 12/2002

* cited by examiner

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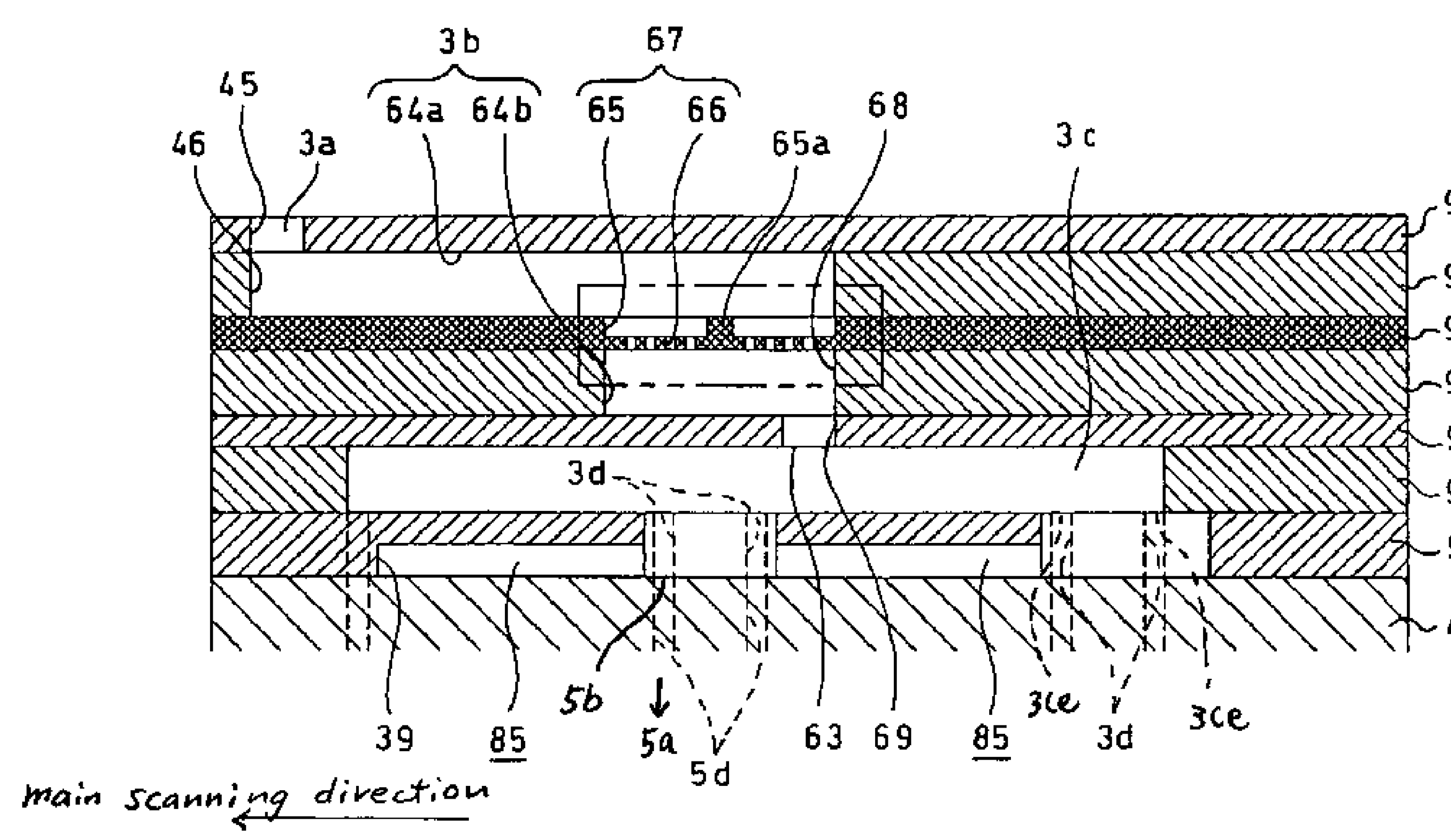
(57) **ABSTRACT**

An ink channel is formed in an inkjet head, so that ink introduced through an ink inlet passes through a pressure chamber and is ejected out of a nozzle. A filter for filtering the ink is disposed in the ink channel. The filter includes a depression formed in a plate, and a plurality of through-holes formed in the bottom of the depression. The filter has small channel resistance and is easy to handle.

23 Claims, 12 Drawing Sheets



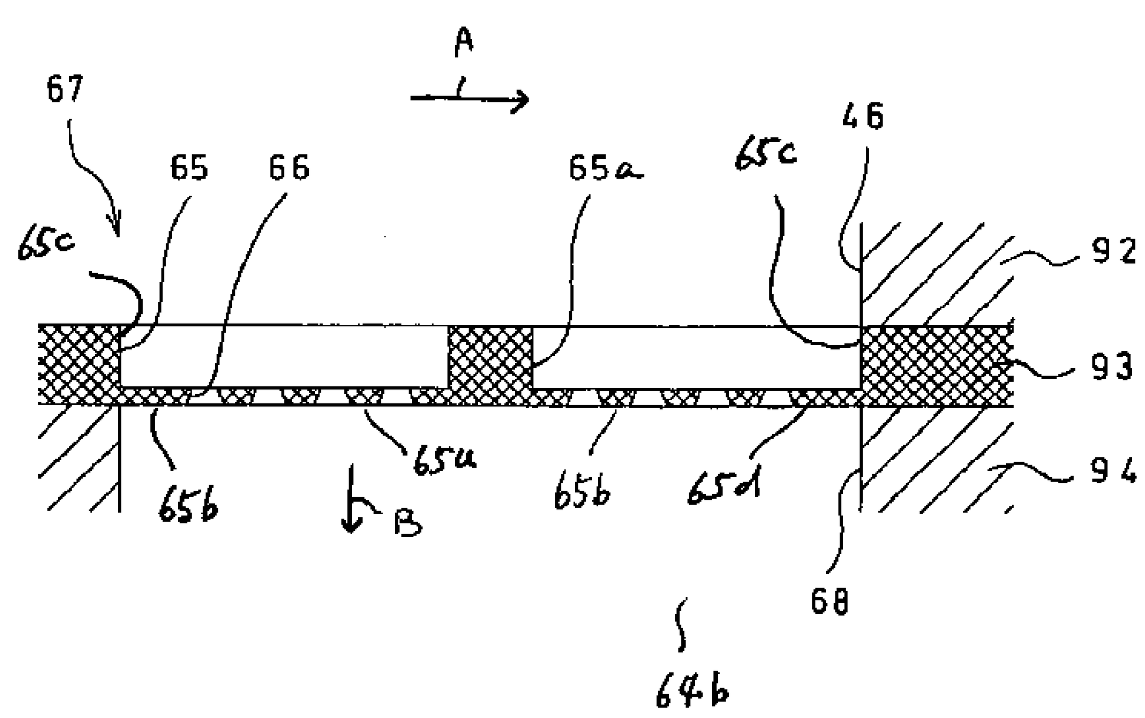


FIG. 1

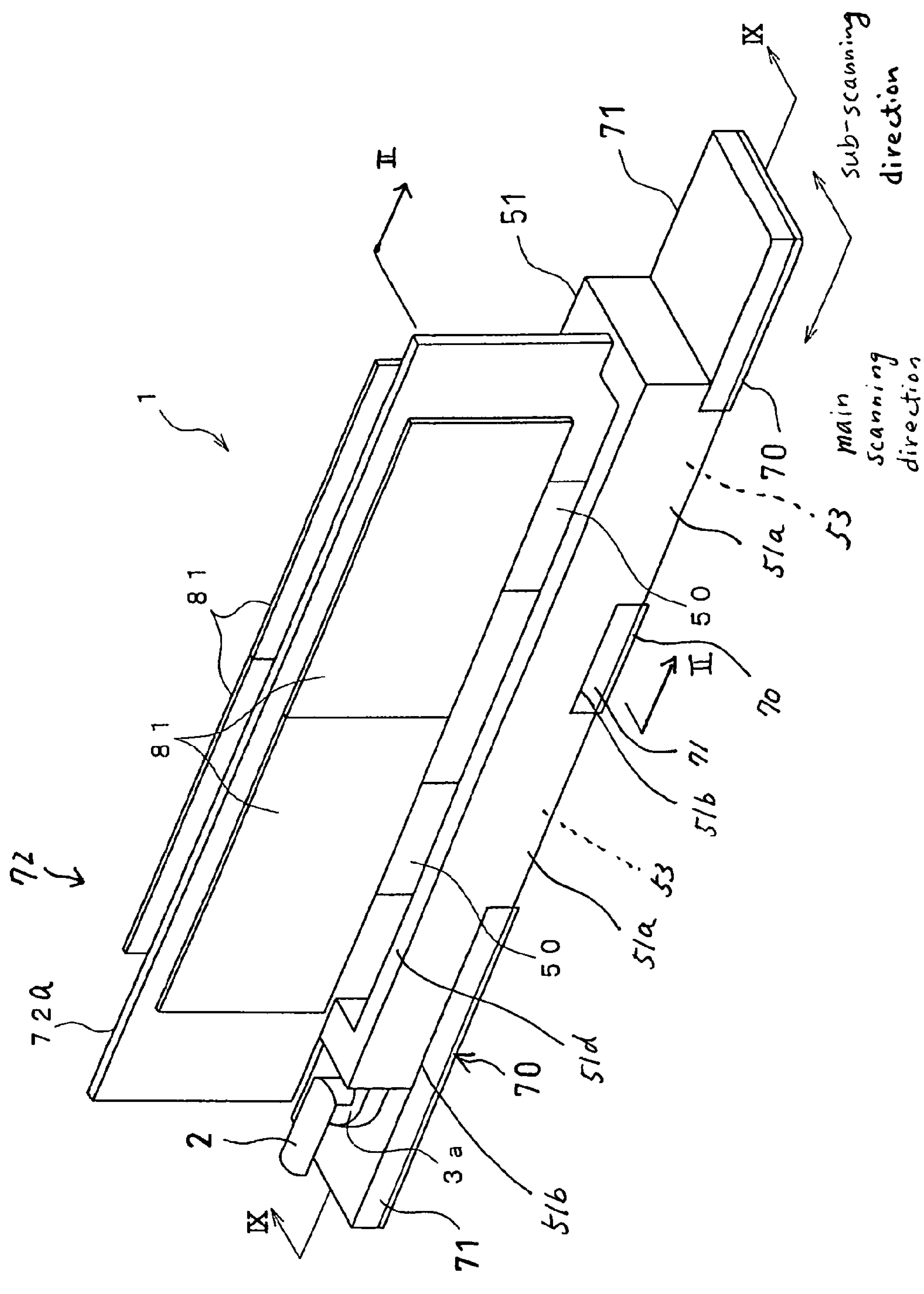

1
2
3a
50
50
51
51a
51a
51b
51b
51d
53
53
70
70
70
71
71
71
72
72a
81
81
II
II
IX
IX
sub-scanning direction
main scanning direction

FIG. 2

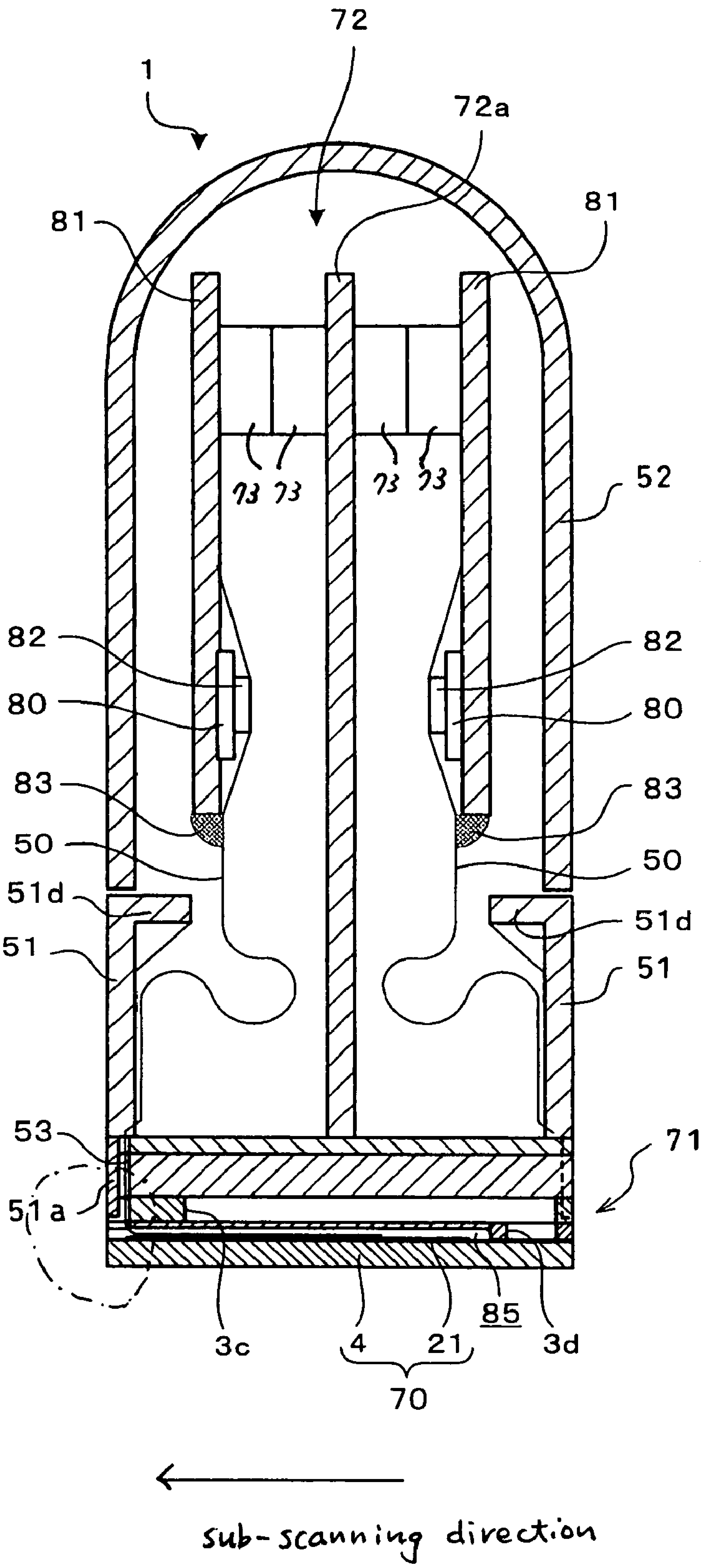

72
1
72a
81
81
73 73
73 73
52
82
82
80
80
83
83
50
50
51d
51d
51
51
53
71
51a
3c
4
21
85
3d
70
sub-scanning direction

FIG. 3

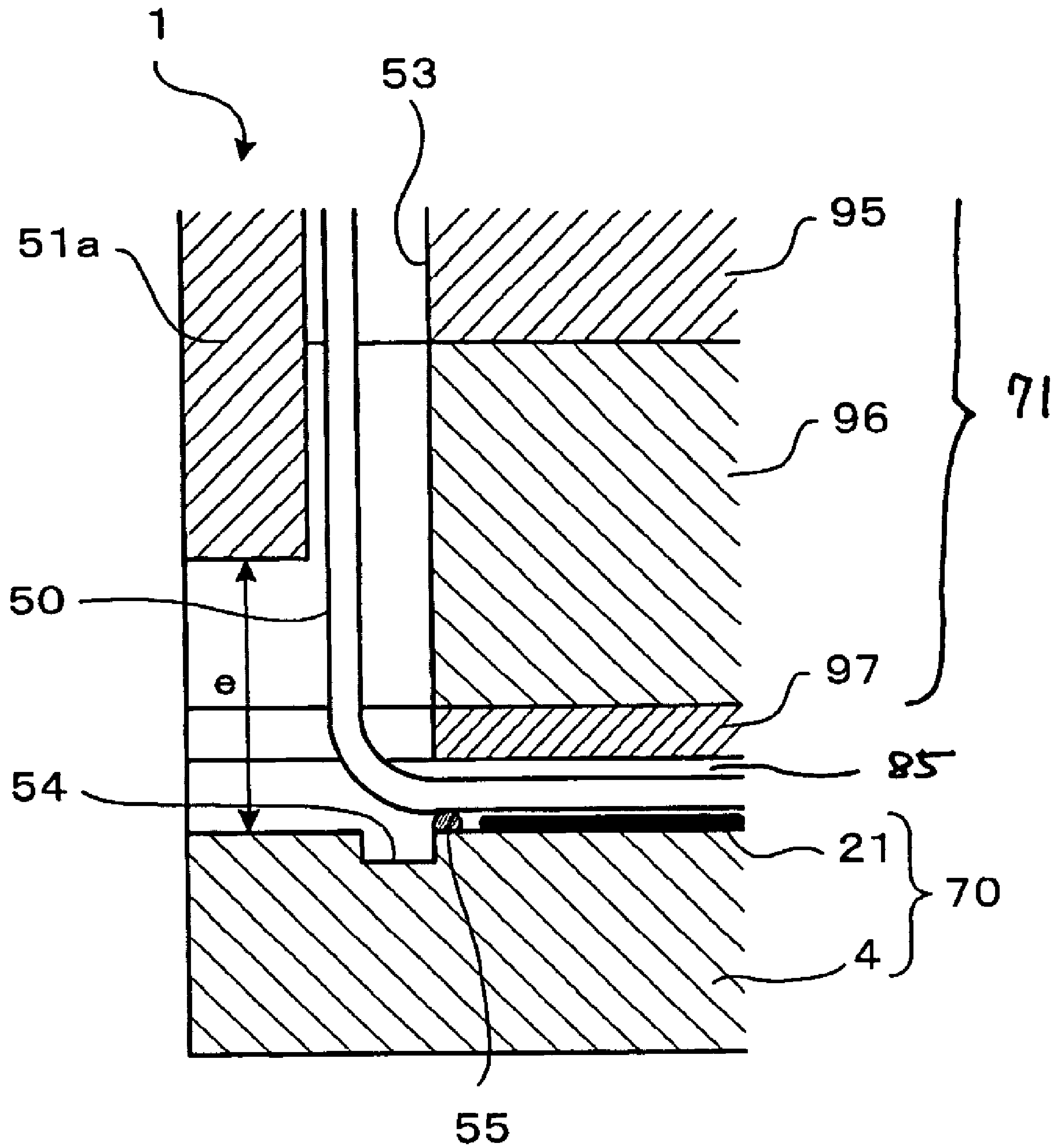
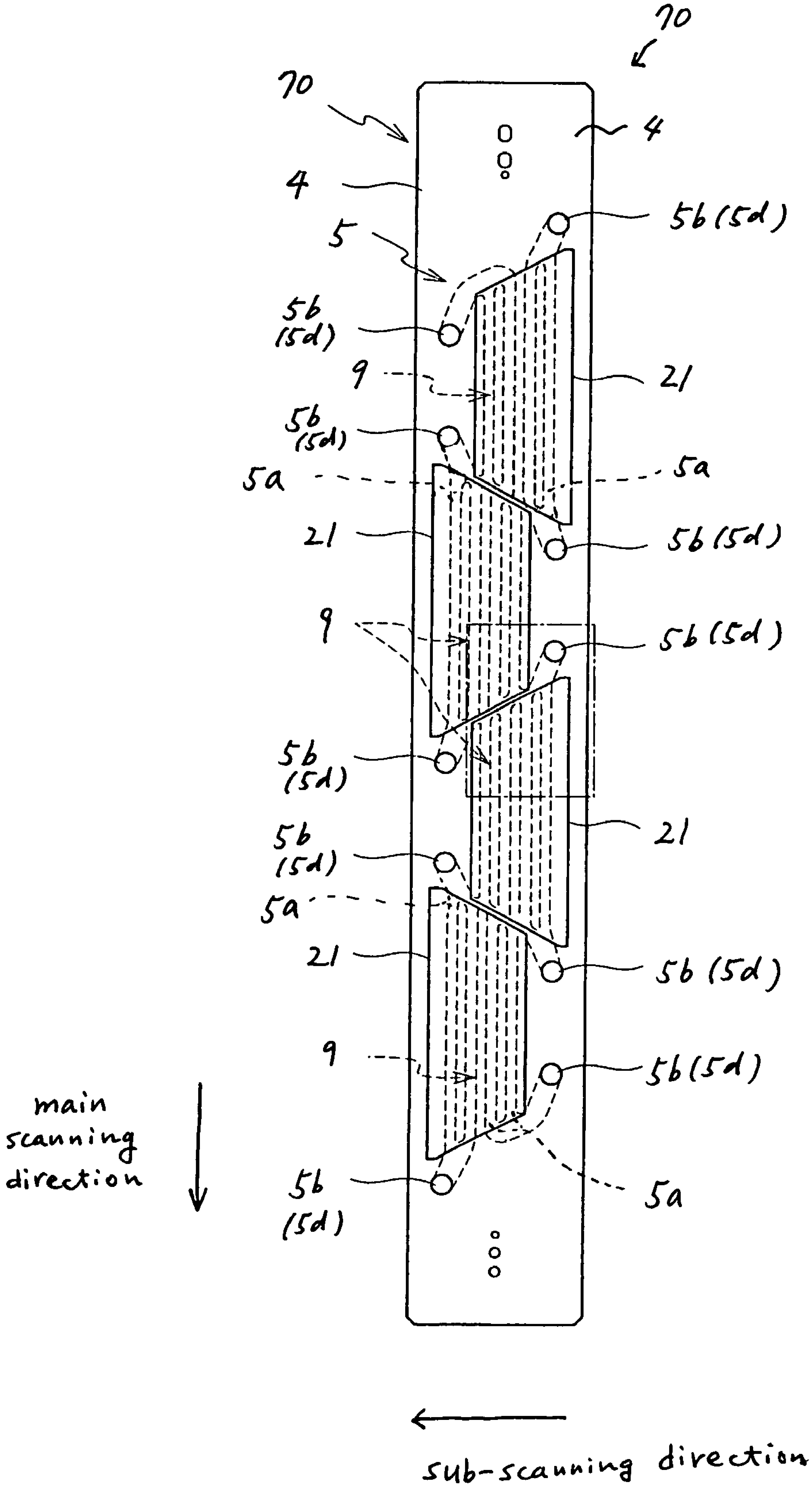


FIG. 4



70
70
4
4
5
5b(5d)
5b (5d)
9
21
5b (5d)
5a
5a
21
5b(5d)
9
5b(5d)
5b (5d)
21
5b (5d)
5a
21
5b (5d)
9
5b(5d)
main scanning direction
5b (5d)
5a
sub-scanning direction

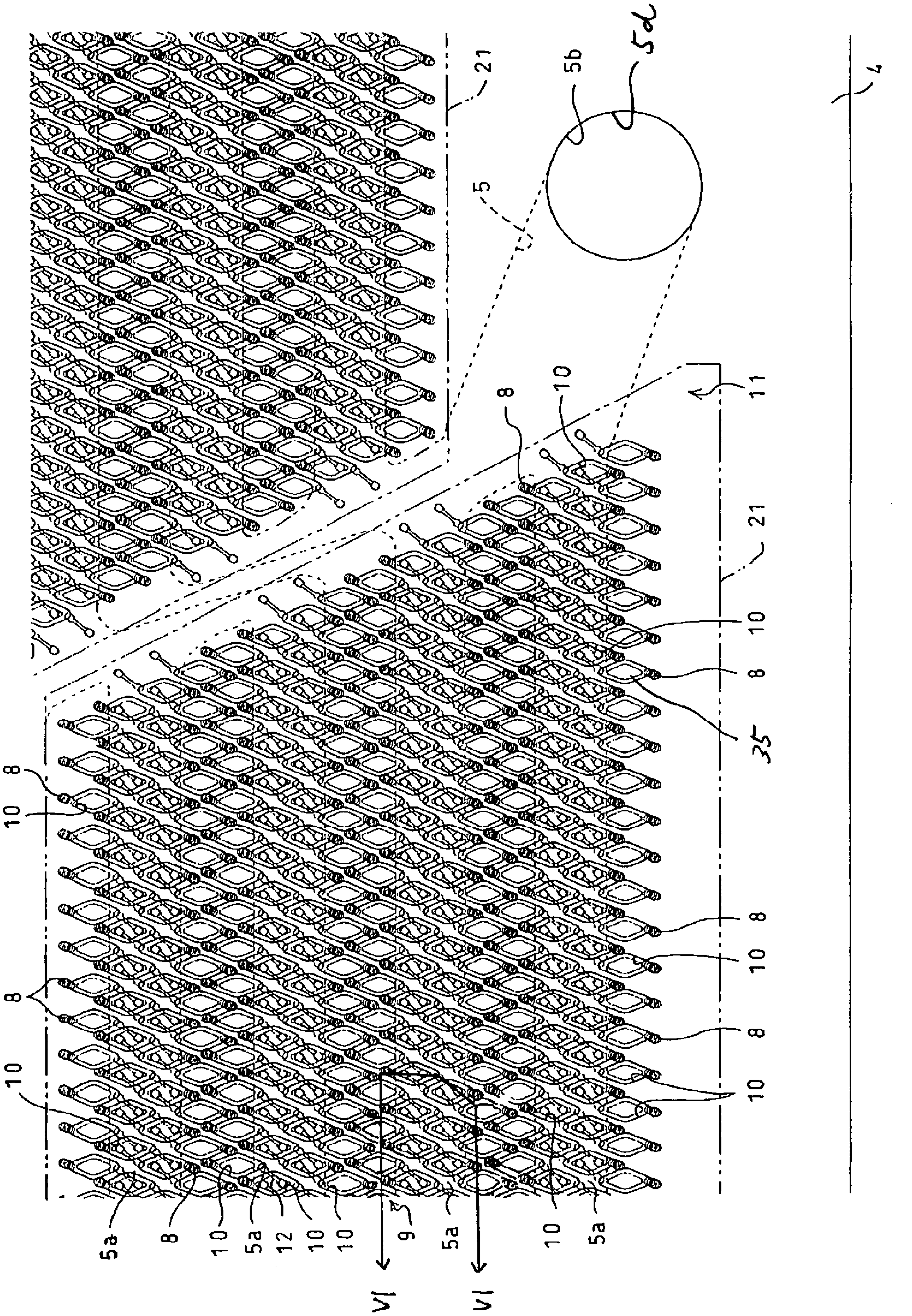


FIG. 5

FIG. 6(a)

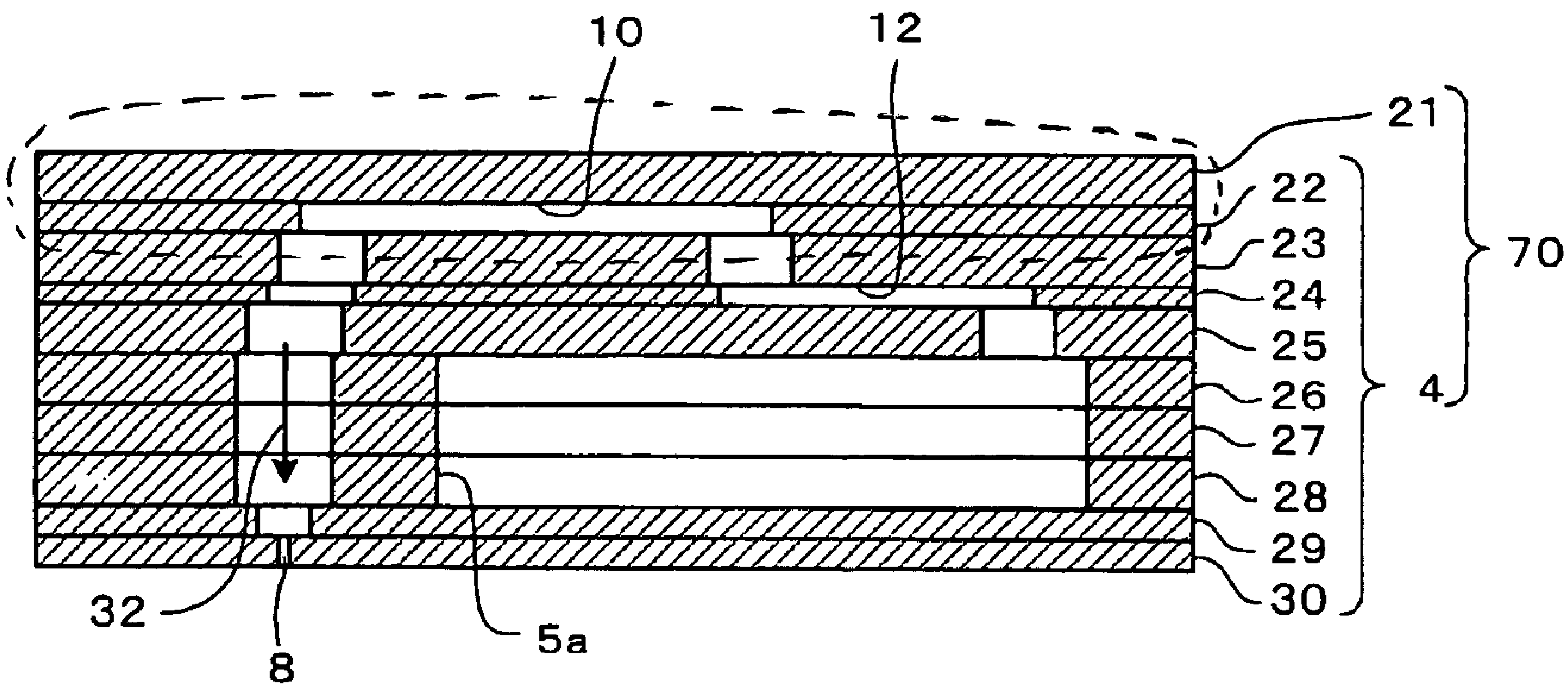


FIG. 6(b)

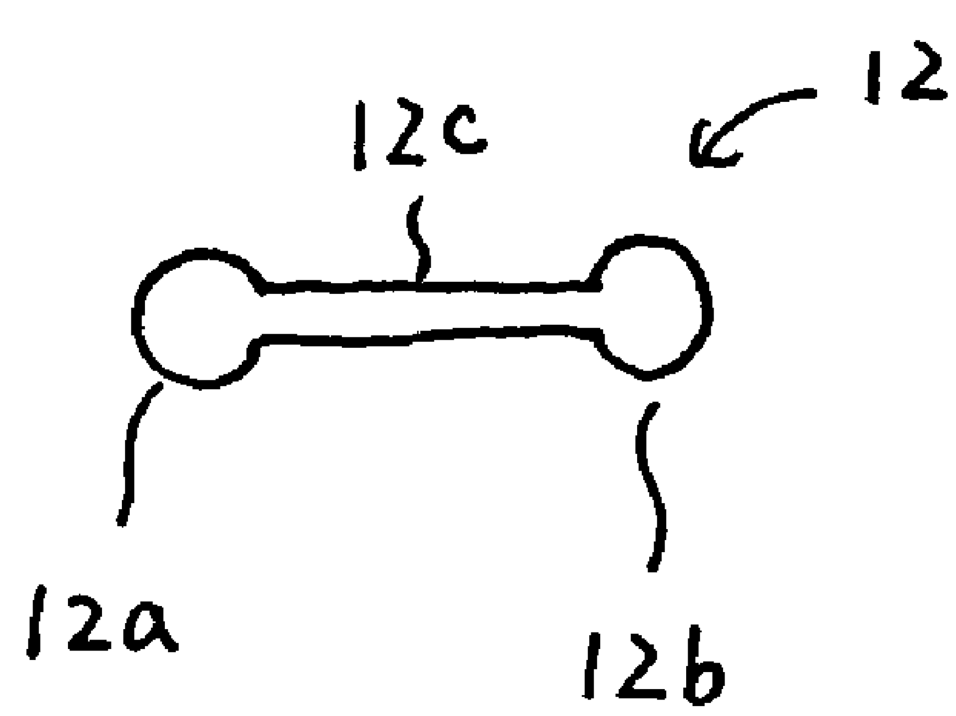


FIG. 7

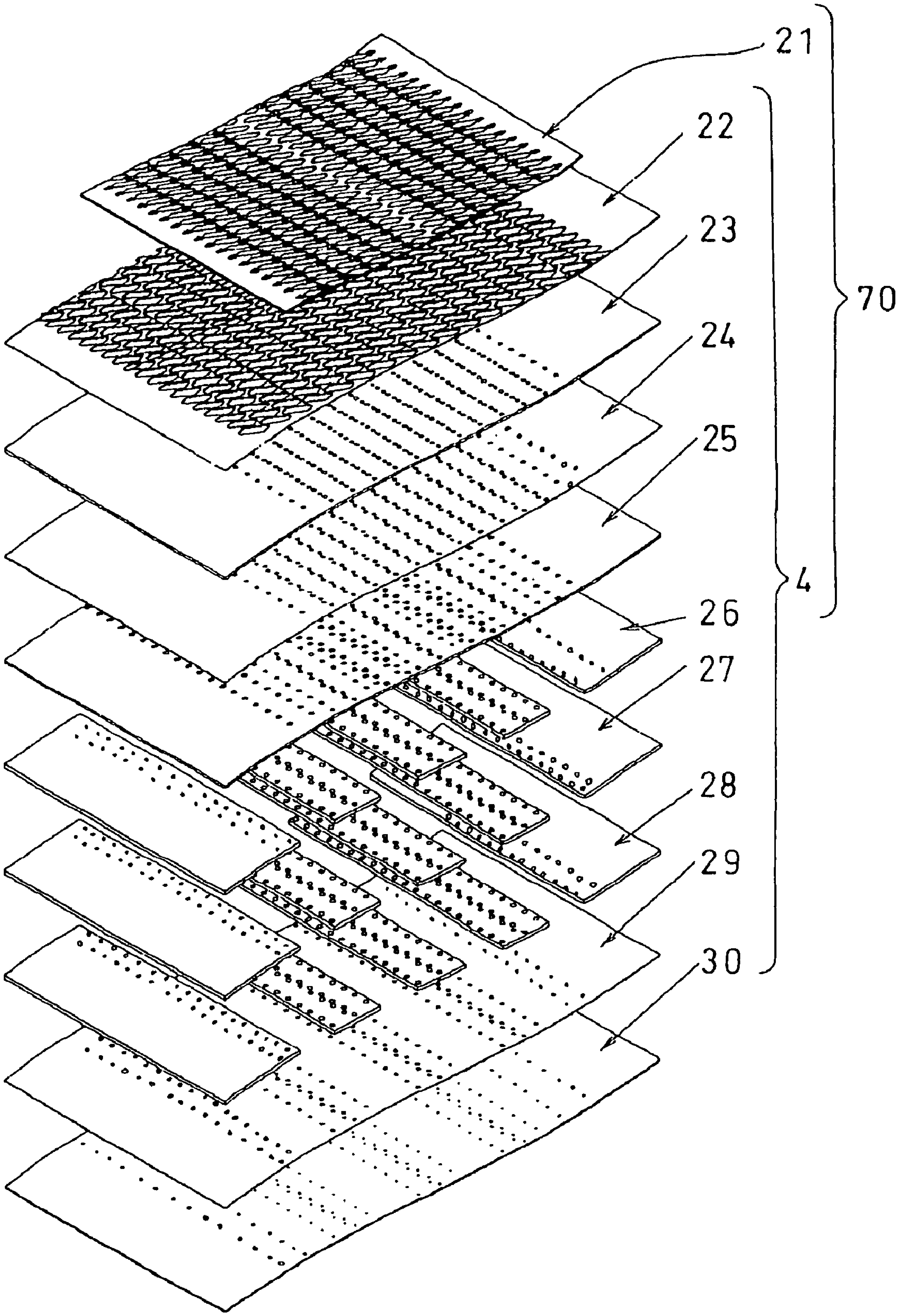


FIG. 8(a)

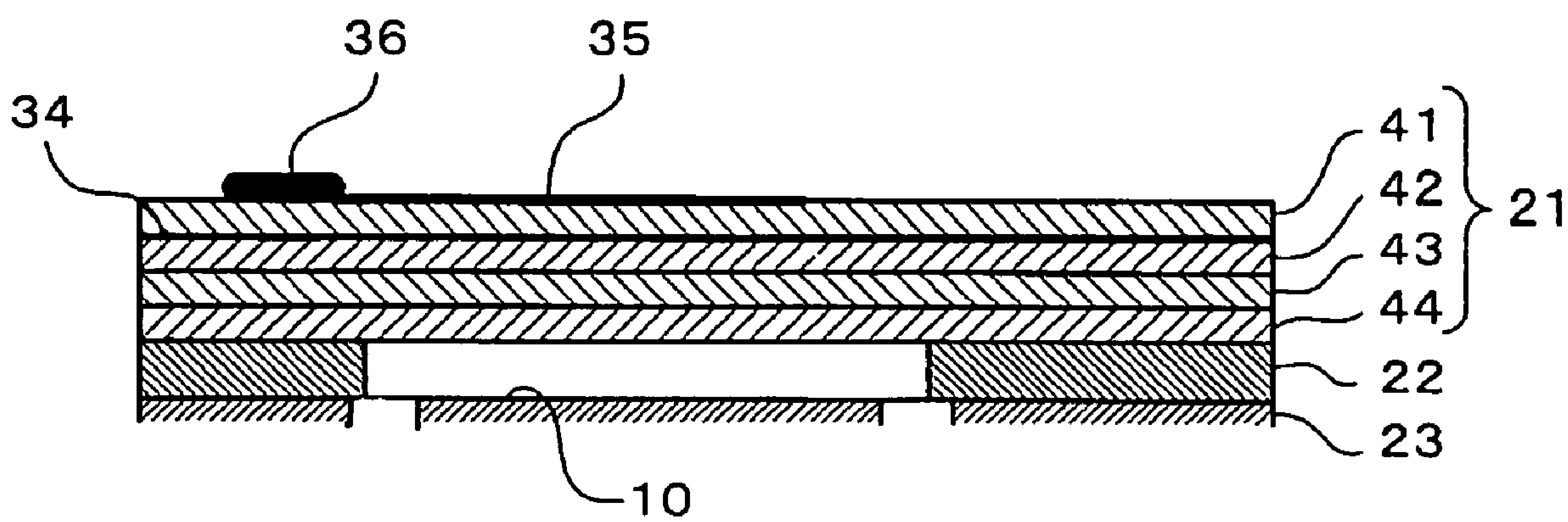


FIG. 8(b)

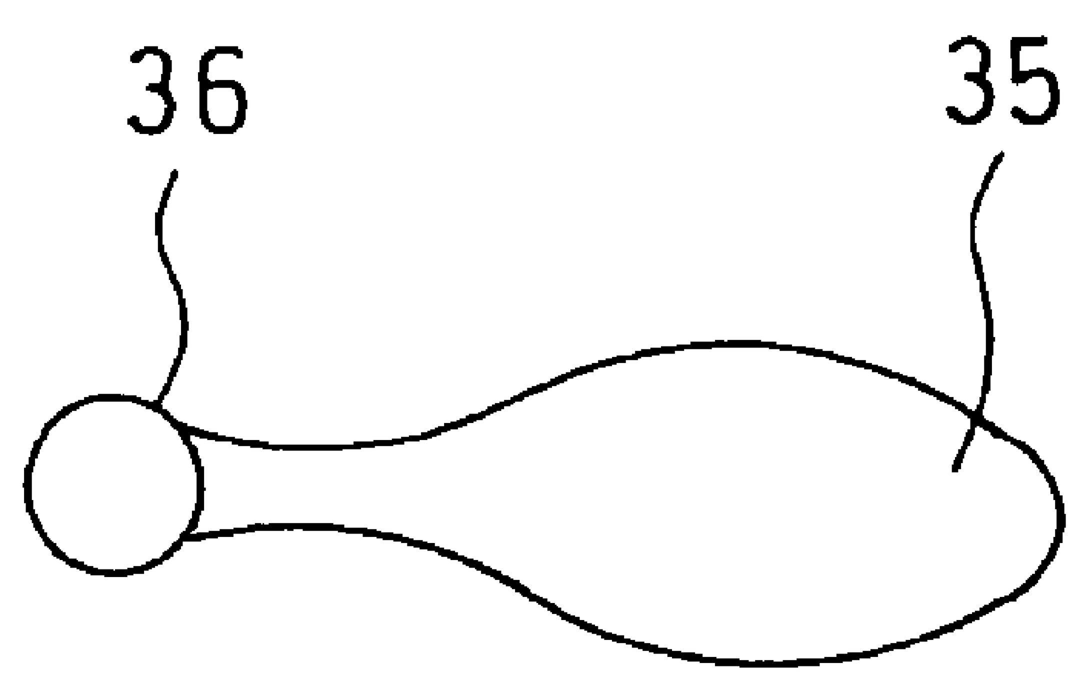


FIG. 9 (a)

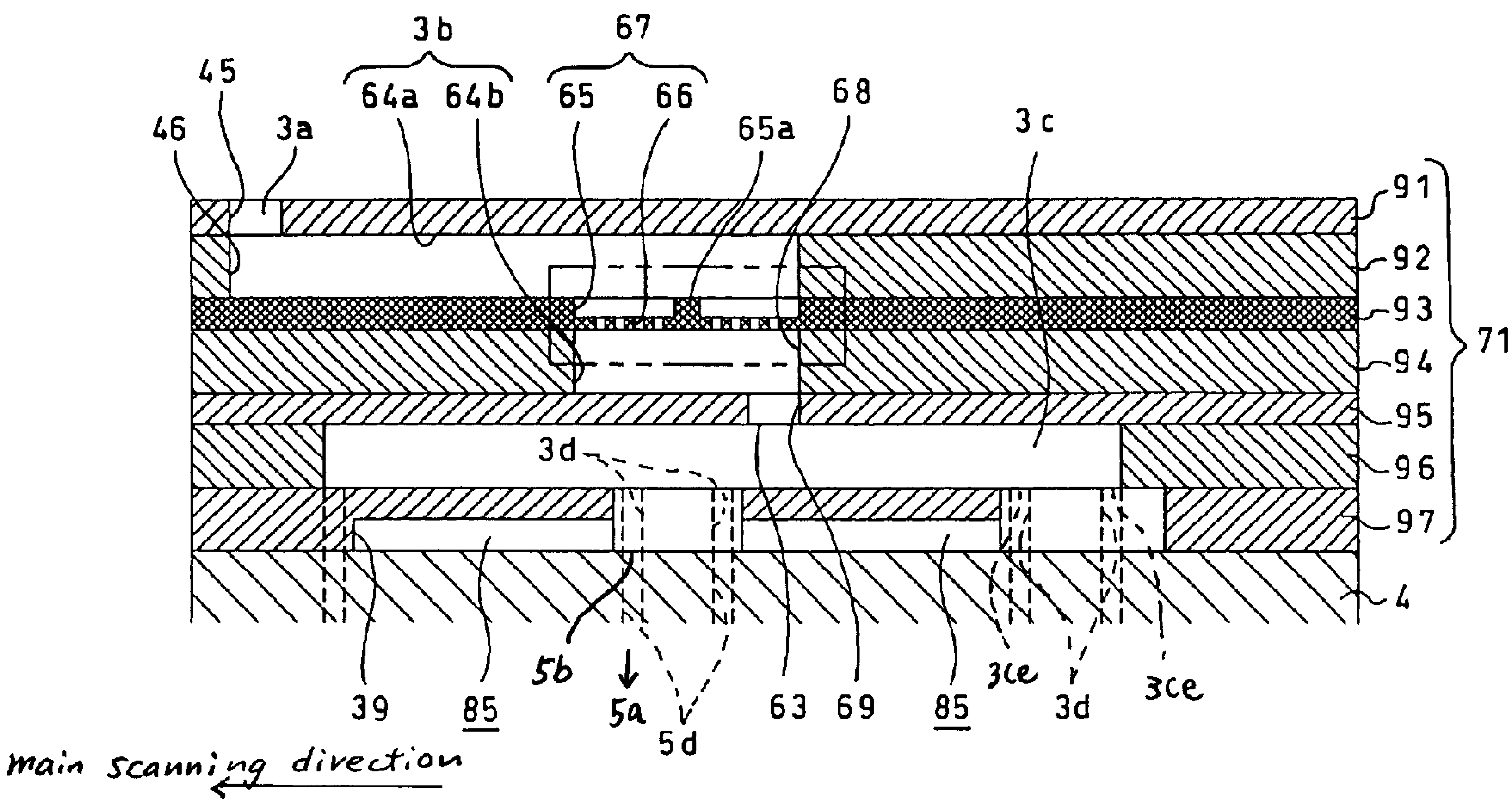

3b
67
45
64a 64b
65 66
68
46
3a
65a
3c
91
92
93
94
71
95
96
97
4
3d
39
85
5b
5a
5d
63
69
85
3ce
3d
3ce
main scanning direction

FIG. 9 (b)

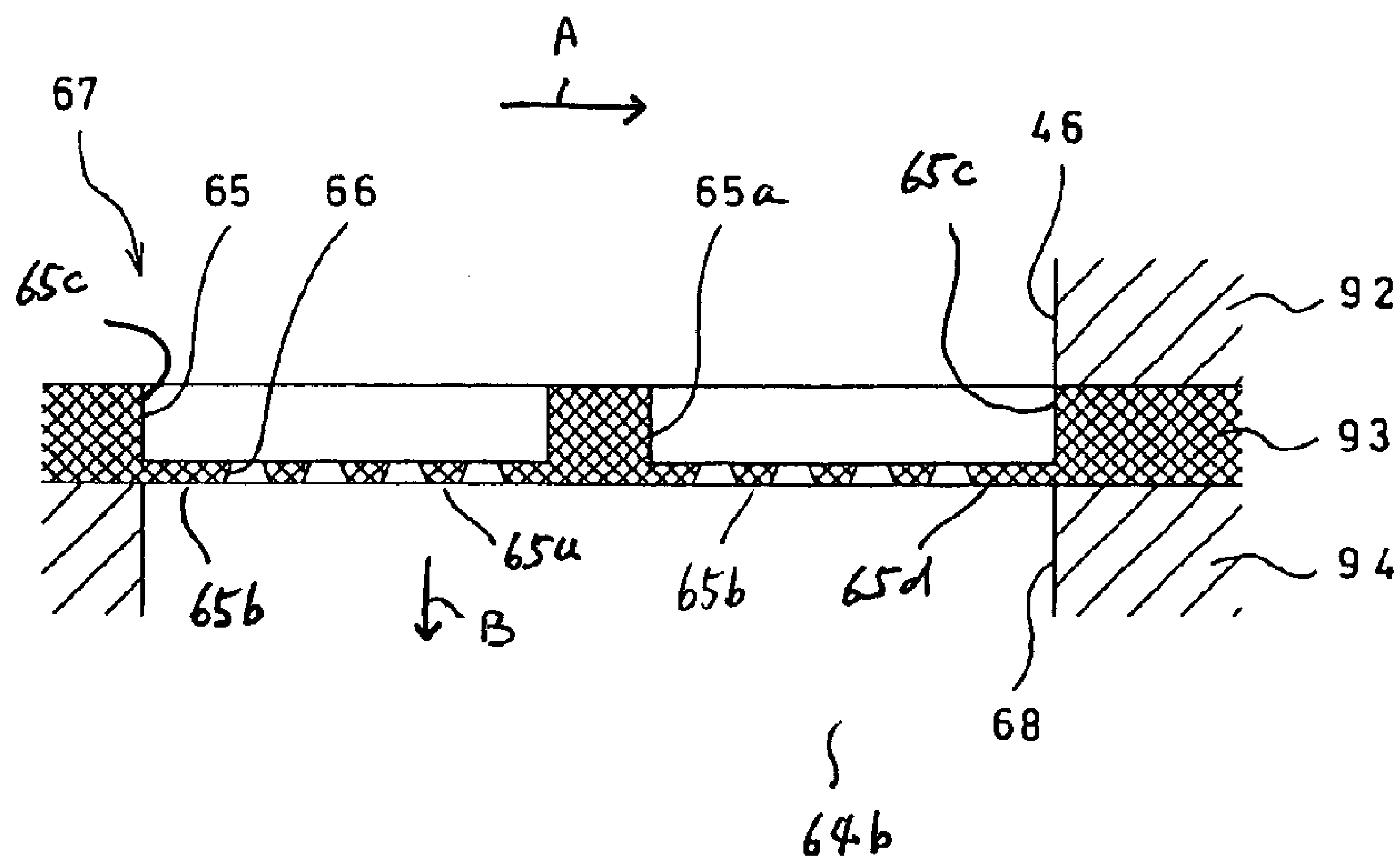

A
67
65 66
65a
65c
46
65c
92
93
65b
65a
B
65b
65d
94
68
64b

FIG. 10

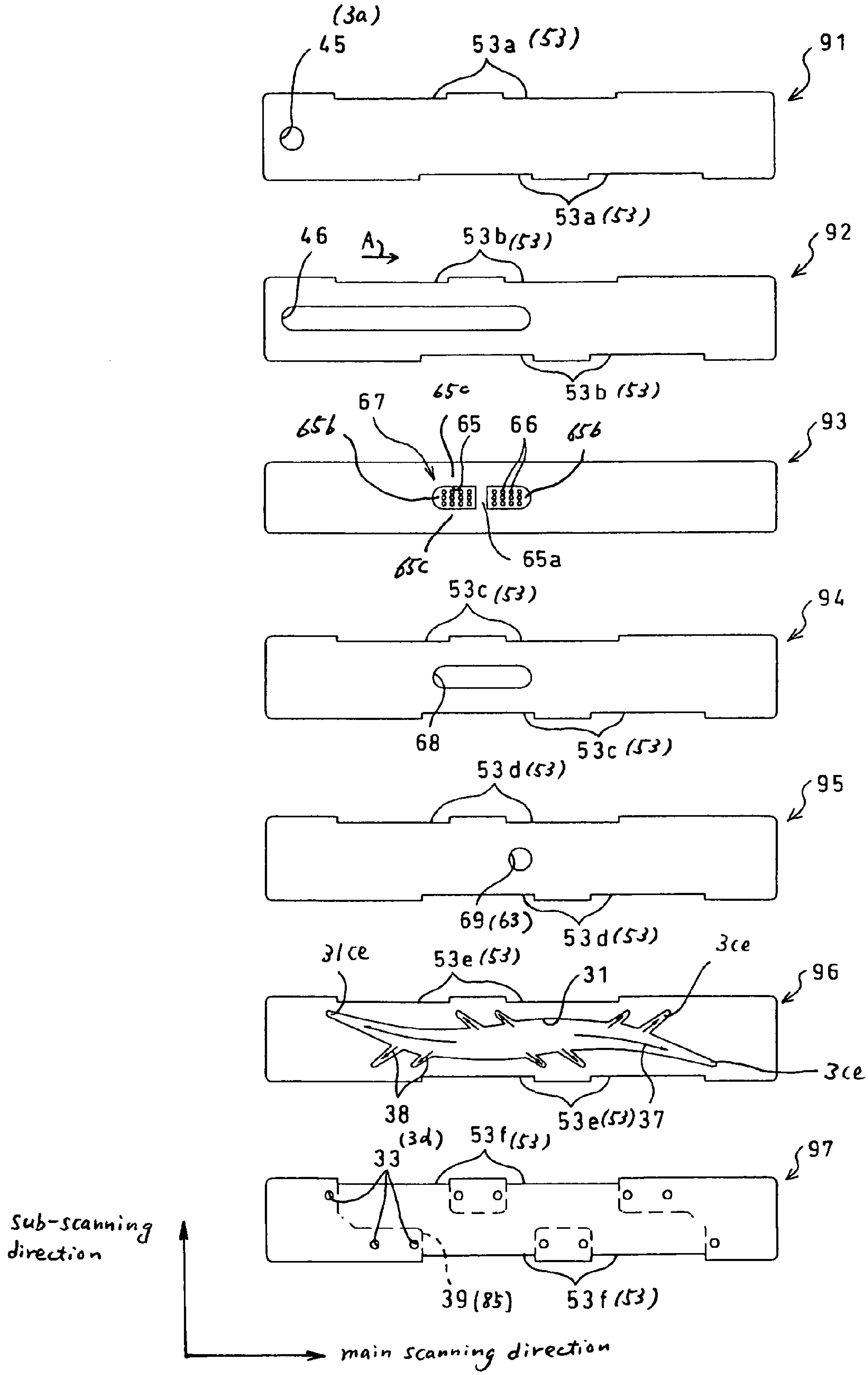

(3a)
45
53a (53)
91
53a (53)
46
A
53b (53)
92
53b (53)
67
65c
65b
65
66
65b
93
65c
65a
53c (53)
94
68
53c (53)
53d (53)
95
69 (63)
53d (53)
31ce
53e (53)
31
3ce
96
3ce
38
53e (53) 37
(3d)
33
53f (53)
97
39 (85)
53f (53)
sub-scanning direction
main scanning direction

FIG. 11(a)

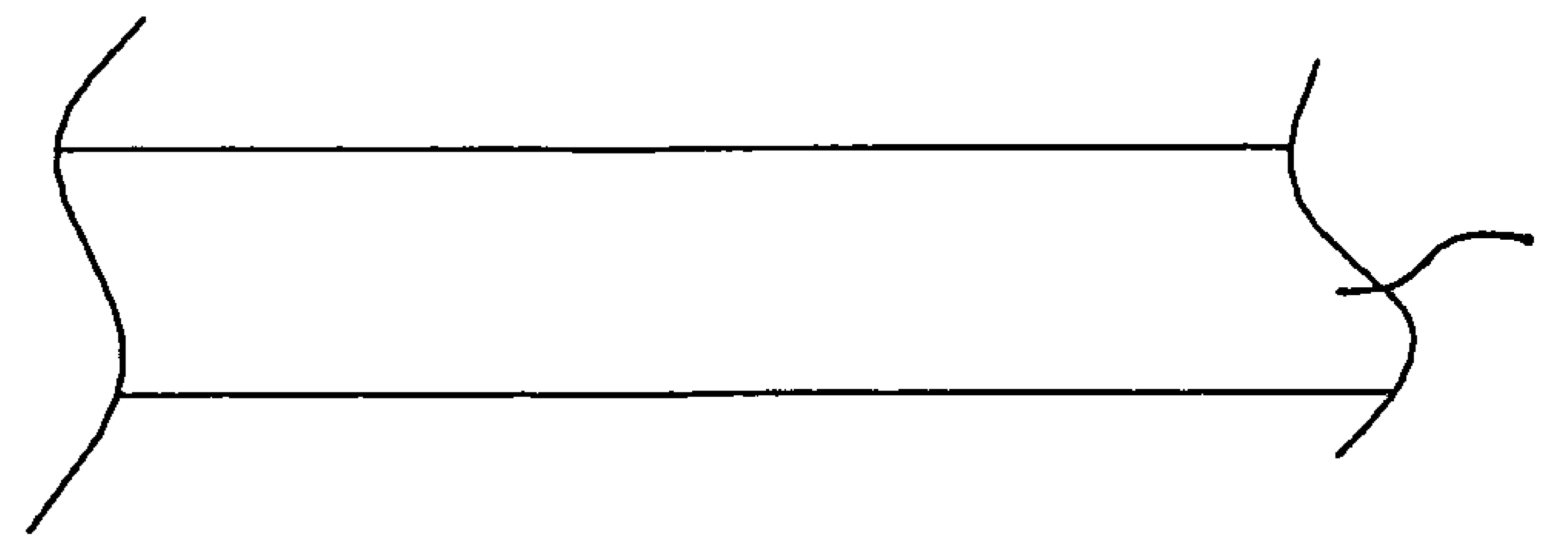


FIG. 11(b)

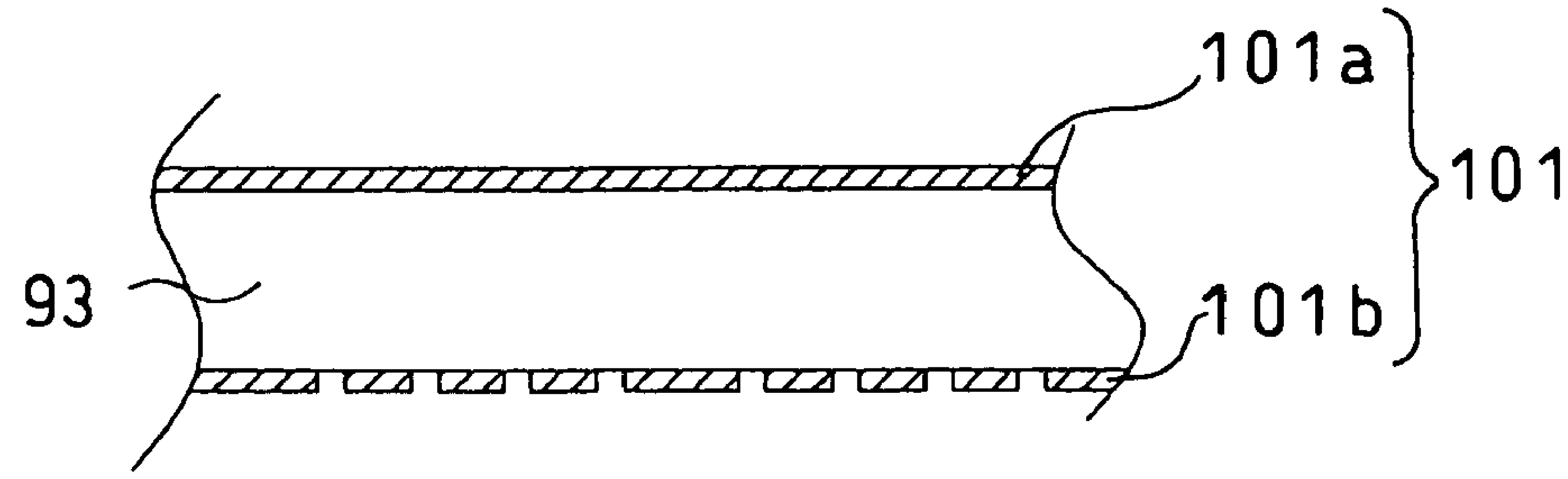


FIG. 11(c)

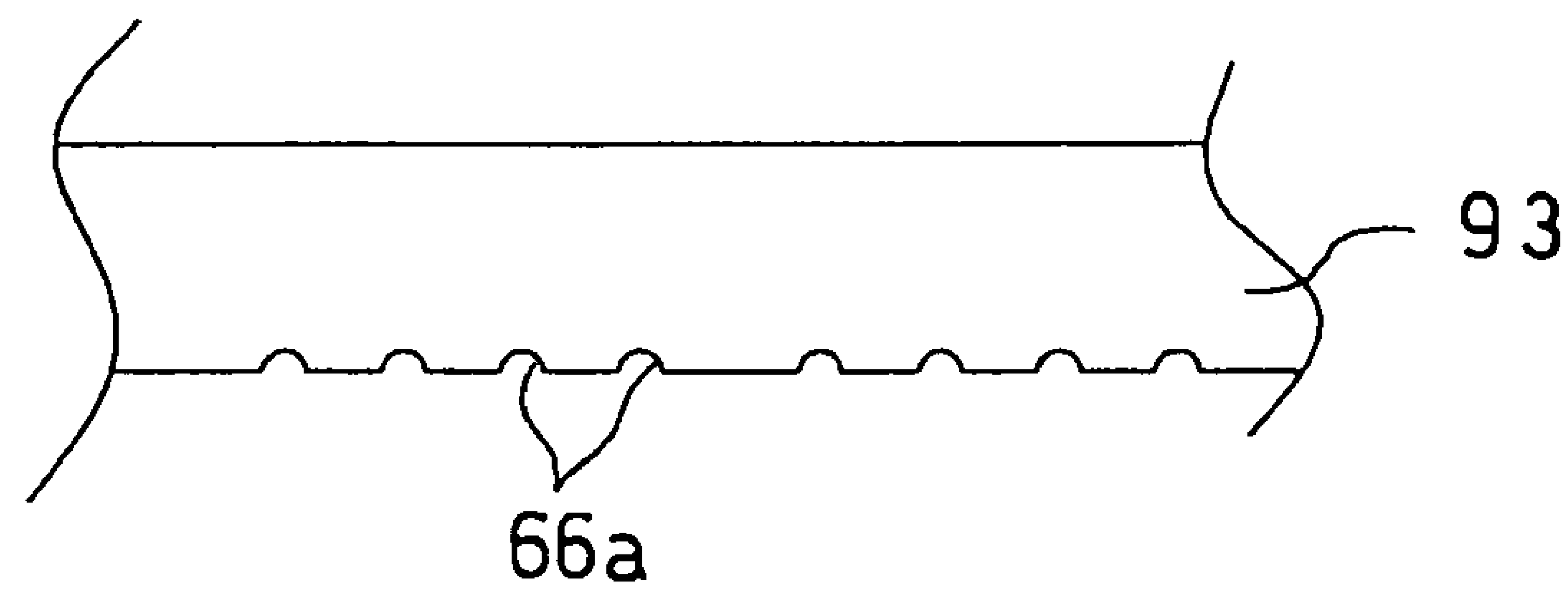


FIG. 11(d)

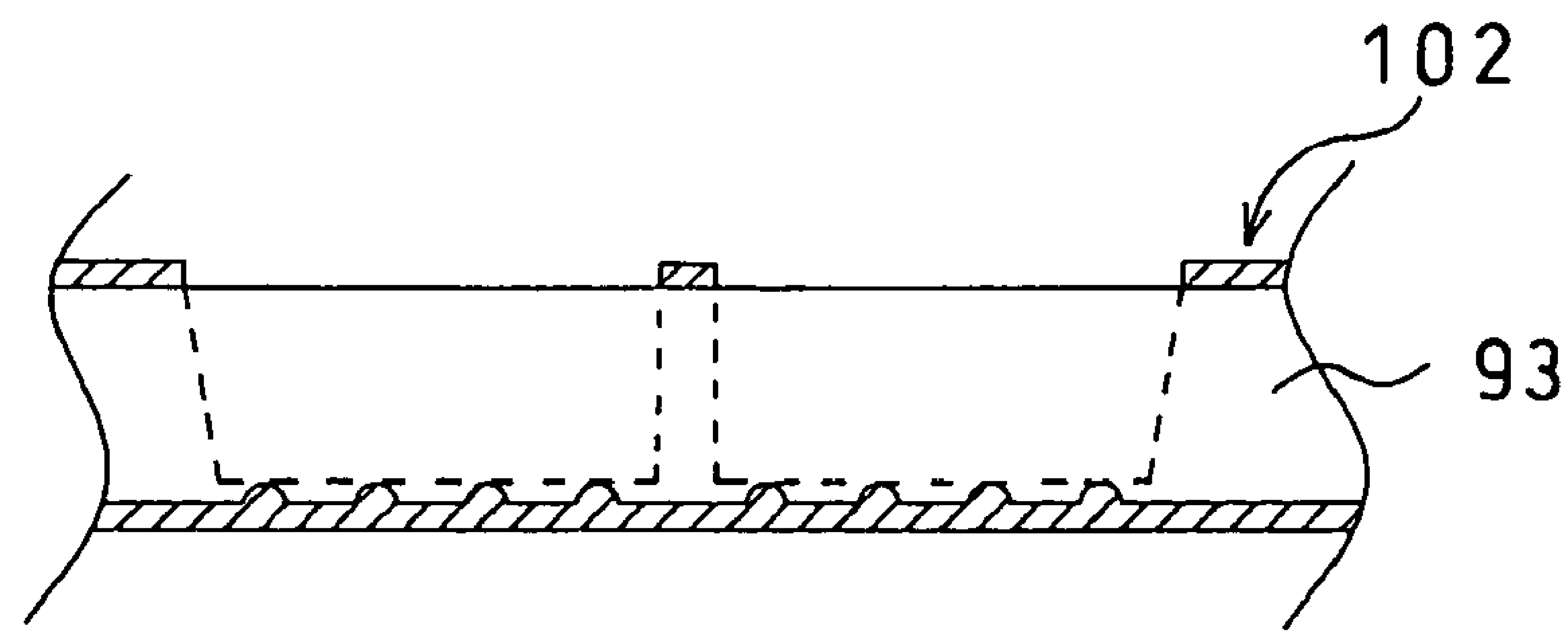


FIG. 11(e)

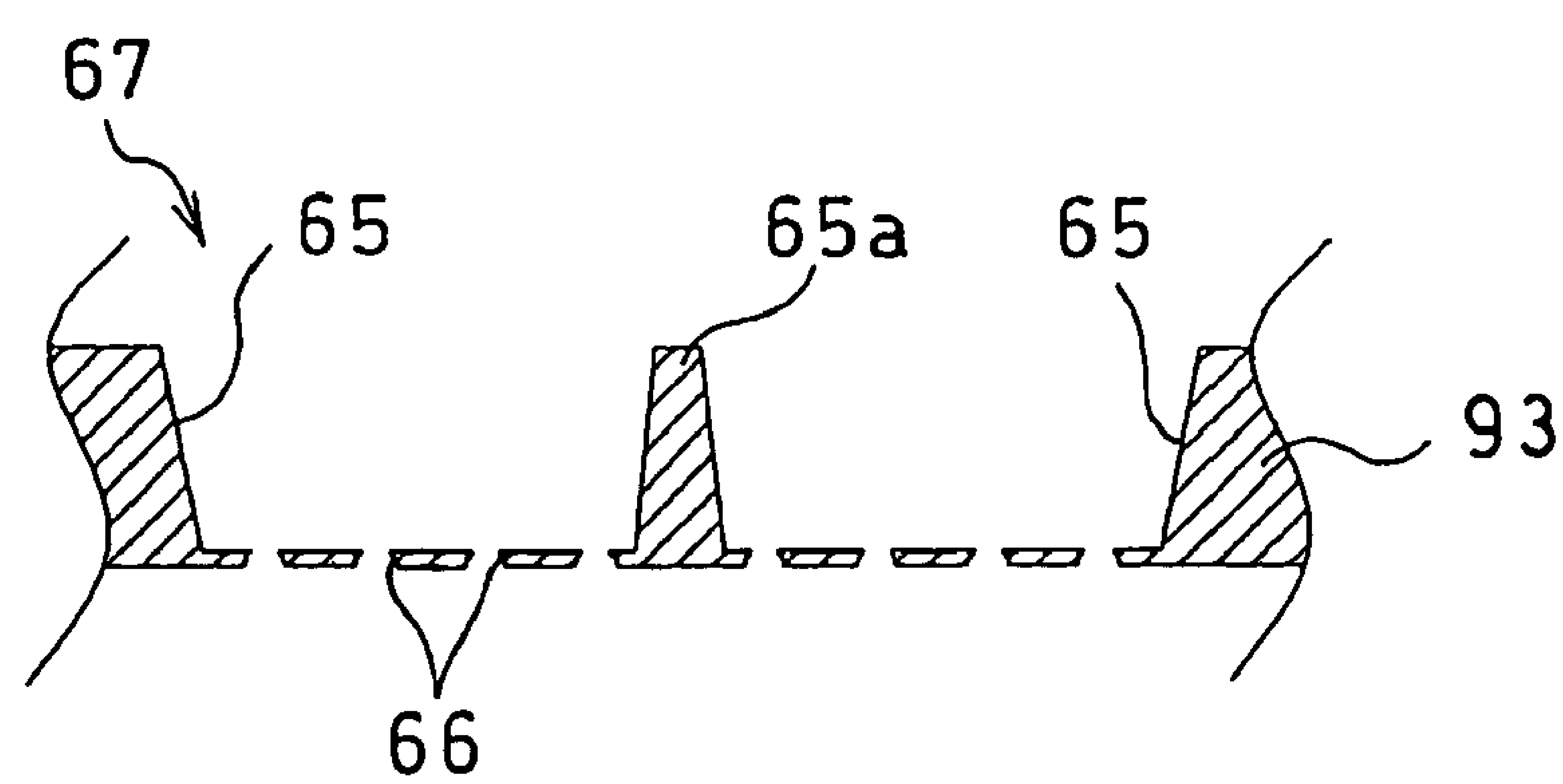


FIG. 12(a)

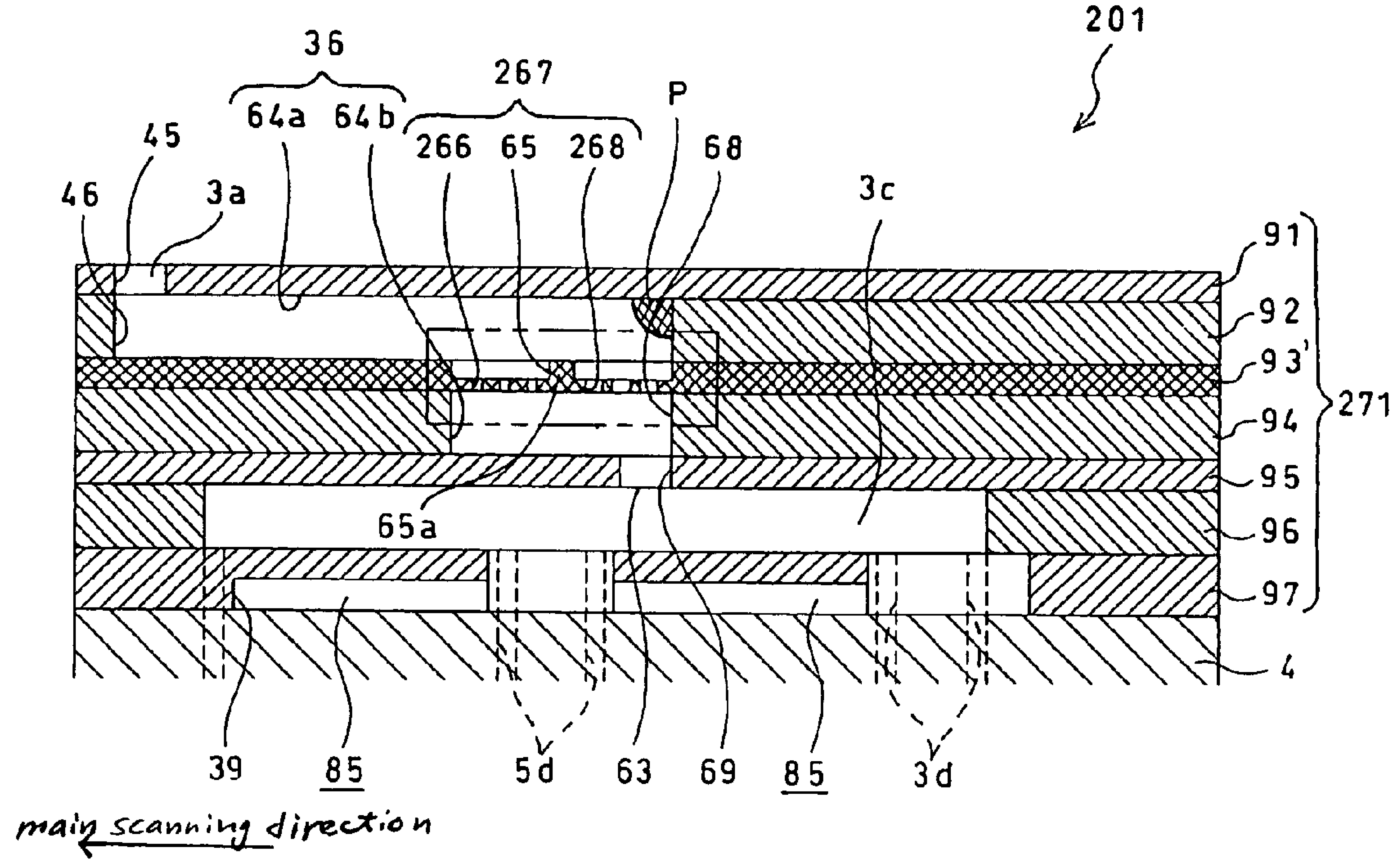
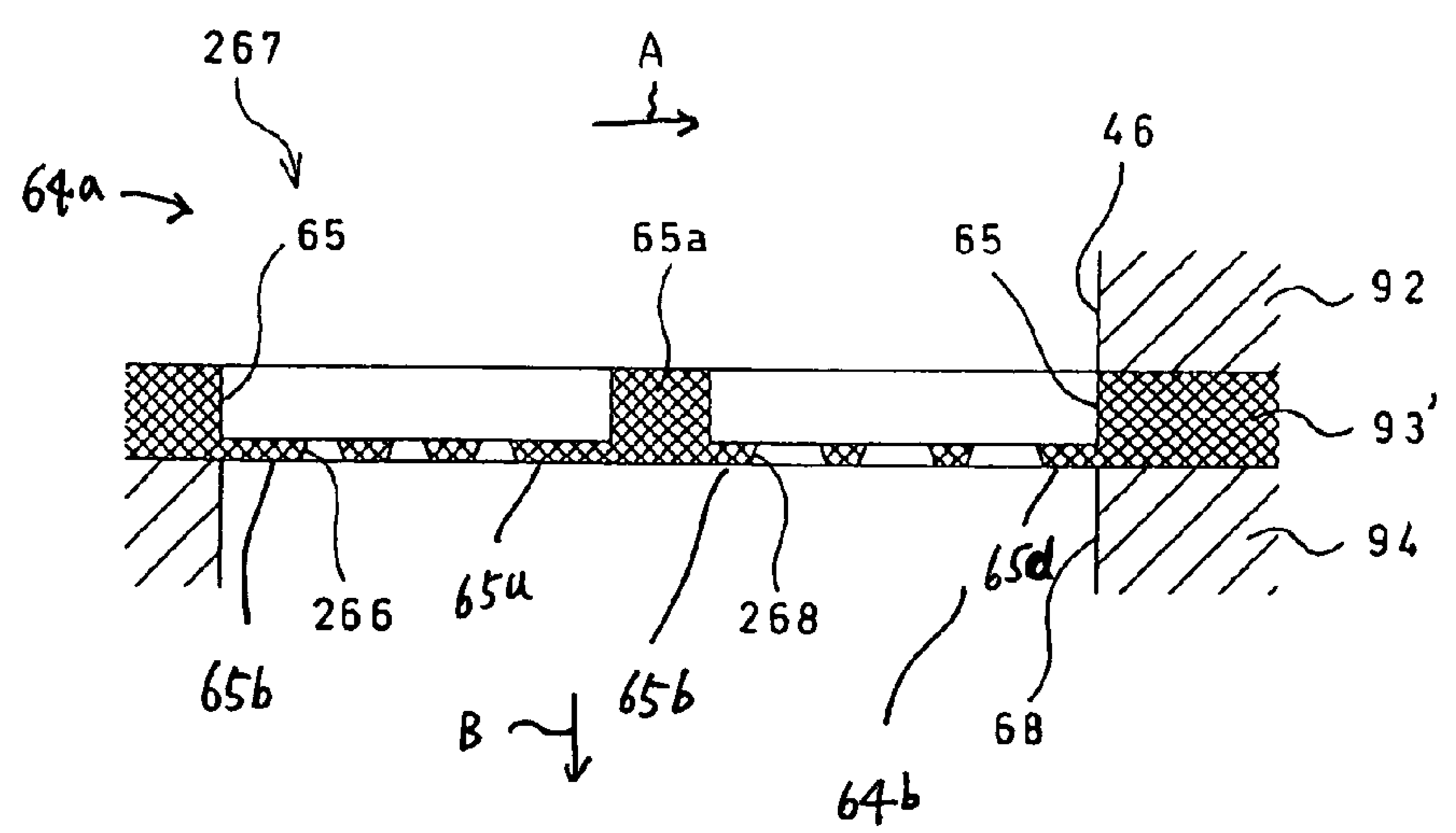


FIG. 12(b)



INKJET HEAD, FILTER PLATE FOR INKJET HEAD, AND METHOD OF MANUFACTURING FILTER PLATE

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to an inkjet head for performing a printing operation by ejecting ink onto a recording medium; a filter plate for an inkjet head having a filter for trapping foreign matter in the ink; and a method for manufacturing the filter plate.

2. Description of Related Art

Japanese unexamined patent application publication No. HEI-6-255101 discloses an inkjet head configured of laminated channel plates and having nozzles for ejecting ink, ink pressure chambers for applying pressure to the ink, a common ink chamber for distributing ink to each of the ink pressure chambers, and a supply channel for supplying ink from an ink tank to the common ink chamber. In this ink-jet head, a filter having a plurality of through-holes formed by etching or the like is disposed between the common ink chamber and the supply channel. Accordingly, foreign matter in ink supplied from the ink tank can be trapped by the filter so that the matter does not enter the common ink chamber. Therefore, the inkjet head can prevent problems in ink ejection caused by foreign matter clogging the ink channel.

SUMMARY OF THE INVENTION

However, in the inkjet head disclosed in the document described above, the channel plate in which the filter is formed is extremely thin and weak and, therefore, must be handled delicately when stacked with the other channel plates, making the laminating process difficult.

To resolve this problem, it is conceivable to use a thicker channel plate. However, when forming filter through-holes in the channel plate by etching, for example, the diameter of the through-holes grows larger in proportion to the thickness of the plate, giving rise to a new problem of a filter having an insufficient capacity to trap foreign matter, which capacity determines the filtering characteristics.

When forming through-holes by etching, generally a resist layer having openings approximately the same diameter as the filter through-holes is coated on one surface of the channel plate, and the regions exposed in the openings are etched by a chemical solution. However, since the etching proceeds isotropically and not only in the thickness direction of the plate, by the time through-holes are formed penetrating a thick plate, the etching has proceeded also to the underside of the resist layer, resulting in through-holes with a large diameter.

Therefore, it is an object of the present invention to provide an inkjet head that improves the strength of the plate in which a filter portion is formed without a loss in filtering characteristics, making the plate easy to handle.

It is another object of the present invention to provide a filter plate that is strong and easy to handle, without a loss in filtering characteristics, and a method for manufacturing such a filter plate.

In order to attain the above and other objects, the present invention provides an inkjet head including a plurality of laminated plates. The plates have holes that are arranged in communication with one another to form an ink channel. At least one of the plurality of plates includes a filter portion disposed in the ink channel. The filter portion includes a

bottom wall portion defining a depression thereon. A plurality of filter through-holes are formed through the bottom wall portion.

According to another aspect, the present invention provides a filter plate for an inkjet head. The inkjet head includes a plurality of laminated plates. The plurality of plates include the filter plate. The plurality of laminated plates have holes that are arranged to form an ink channel. The filter plate includes a filter portion. The filter portion is disposed in the ink channel which is formed when the plurality of plates are laminated together. The filter portion includes a bottom wall portion defining a depression thereon. A plurality of filter through-holes are formed through the bottom wall portion.

According to another aspect, the present invention provides a method of manufacturing a filter plate serving as a component of an inkjet head including a plurality of laminated plates. The plates have holes that are arranged to form an ink channel. The filter plate has a filter portion that traps foreign matter in ink in the ink channel. The method includes: forming a plurality of holes within a predetermined region on one surface of a metal plate, the holes having a depth smaller than the thickness of the metal plate; and forming filter through-holes penetrating the metal plate by etching a depression across the entire predetermined region on the opposite surface of the metal plate, the depression connecting the holes, thereby forming through-holes.

According to another aspect, the present invention provides a filter plate for an inkjet head. The inkjet head includes a plurality of laminated plates including the filter plate. The plurality of laminated plates have holes that are arranged to form an ink channel. The filter plate is formed with a depression that is to be located in the ink channel when the plurality of plates are laminated together. A plurality of filter through-holes are formed through a bottom portion of the depression.

According to another aspect, the present invention provides an inkjet head including a plurality of laminated plates. The plates have holes that are arranged in communication with one another to form an ink channel. At least one of the plurality of plates is formed with a depression at a location in the ink channel. A plurality of filter through-holes are formed through a bottom of the depression.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and other objects, features and advantages of the invention will become more apparent from reading the following description of the preferred embodiments taken in connection with the accompanying drawings in which:

FIG. **1** is an external perspective view of an ink-jet head according to a first embodiment of the present invention;

FIG. **2** is a cross-sectional view taken along a line II—II in FIG. **1**;

FIG. **3** is an enlarged view of a region in FIG. **2** surrounded by a one-dot-and-one-chain line;

FIG. **4** is a plan view of a main head member shown in FIG. **1**;

FIG. **5** is an enlarged plan view of a region in FIG. **4** surrounded by a one-dot-and-one-chain line;

FIG. **6**(*a*) is a cross-sectional view taken along a line VI—VI in FIG. **5**;

FIG. **6**(*b*) is a plan view of an aperture shown in FIG. **6**(*a*);

FIG. **7** is an exploded perspective view showing a portion of the main head member depicted in FIG. **5**;

FIG. **8**(*a*) is an enlarged cross-sectional view of a portion surrounded by a broken line in FIG. **6**(*a*);

FIG. **8**(*b*) is a plan view of an individual electrode shown in FIG. **8**(*a*);

FIG. **9**(*a*) is a cross-sectional view of a reservoir unit taken along a line IX—IX in FIG. **1**;

FIG. **9**(*b*) is an enlarged cross-sectional view of a region in FIG. **9**(*a*) surrounded by a broken line with alternating long and double short dashes;

FIG. **10** is an exploded view of the reservoir unit shown in FIG. **1**;

FIGS. **11**(*a*)–**11**(*e*) illustrate a process for manufacturing a filter in a third plate of the reservoir unit shown in FIG. **1**, wherein FIG. **11**(*a*) shows the third plate as the original plate material prior to forming the filter, FIG. **11**(*b*) shows the third plate after resist layers have been formed over the surfaces thereof, FIG. **11**(*c*) shows the third plate after holes are formed in the bottom surface and the resist layers are removed from the third plate subsequently, FIG. **11**(*d*) shows the third plate after resist layers are again formed on the surfaces thereof, and FIG. **11**(*e*) shows the completed filter formed in the third plate after a depression is formed and the resist layers are removed from the third plate subsequently; and

FIGS. **12**(*a*) and **12**(*b*) are cross-sectional views of the reservoir unit in an inkjet head according to a second embodiment of the present invention, wherein FIG. **12**(*a*) is a cross-sectional view of the entire reservoir unit, and FIG. **12**(*b*) is an enlarged cross-sectional view of a region in FIG. **12**(*a*) surrounded by a broken line with alternating long and double short dashes.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

An inkjet head according to preferred embodiments of the present invention will be described while referring to the accompanying drawings wherein like parts and components are designated by the same reference numerals to avoid duplicating description.

FIG. **1** is an external perspective view of an ink-jet head **1** according to a first embodiment of the present invention. FIG. **2** is a cross-sectional view taken along a line II—II in FIG. **1**. FIG. **3** is an enlarged view of a region in FIG. **2** surrounded by a one-dot-and-one-chain line.

The inkjet head **1** includes: a main head member **70** having a flat rectangular shape extending in a main scanning direction and functioning to eject ink onto paper; a reservoir unit **71** disposed on the top surface of the main head member **70** and having an ink reservoir **3***c* (FIG. **9**(*a*)) for accommodating ink to be supplied to the main head member **70**; a controller **72** disposed above the reservoir unit **71** for controlling the main head member **70**; and a lower cover **51** and an upper cover **52** for protecting the inkjet head **1** from sprayed ink. For the convenience of description, the upper cover **52** is omitted from FIG. **1**, but is shown in FIG. **2**. A sub-scanning direction is defined perpendicularly to the main scanning direction.

As shown in FIGS. **2** and **3**, the main head member **70** includes: a channel unit **4** in which ink channels are formed; and a plurality of (four, in this embodiment) actuator units **21** bonded to the top surface of the channel unit **4** (FIG. **4**). Each actuator unit **21** has a laminated structure in which a plurality of thin plates are stacked and bonded together as will be described with reference to FIG. **8**.

As shown in FIG. **2**, FIG. **9**(*a*), and FIG. **10**, the reservoir unit **71** is formed with a plurality of (ten, in this embodiment) upper ink supply channels **3***d*. The upper ink supply channels **3***d* extend downward and are opened on the bottom surface of the reservoir unit **71**. As shown in FIG. **10**, the upper ink supply channels **3***d* are located near both ends of the reservoir unit **71** with respect to the sub-scanning direction. The reservoir unit **71** contacts the channel unit **4** only at portions surrounding the openings of the upper ink supply channels **3***d* on the bottom surface of the reservoir unit **71**. Accordingly, remaining regions of the reservoir unit **71** other than the portions surrounding the upper ink supply channels **3***d* are located separate from the main head member **70**, forming a space **85**. The actuator units **21** are disposed in the space **85**.

A plurality of (four, in this embodiment) flexible printed circuits (FPCs) **50** are provided for supplying electricity to the plurality of (four, in this embodiment) actuator units **21**, respectively. The FPCs **50** are electrically connected to the top surfaces of the actuator units **21**, respectively. Two FPCs **50** are led away from one side of the channel unit **4** in the sub-scanning direction, while the other two FPCs **50** are led away from the other side of the channel unit **4** in the sub-scanning direction.

As shown in FIG. **1** and FIG. **9**(*a*), the reservoir unit **71** includes: an ink inlet **3***a* and an ink downflow channel (reservoir channel) **3***b*. An ink supply connector **2** is attached to the ink inlet **3***a*. An ink tube (not shown) is connected to the ink supply connector **2**. The ink downflow channel **3***b* has a downflow opening **63**. Ink supplied from an ink tank (not shown) into the ink inlet **3***a* via the ink tube (not shown) and the ink supply connector **2** flows through the ink down-flow channel **3***b*, through the downflow opening **63**, and accumulates in the ink reservoir **3***c*.

Ink accumulated in the ink reservoir **3***c* is supplied from the plurality of the upper ink supply channels **3***d* to a plurality of (ten, in this embodiment) lower ink supply channels **5***d*, which are formed in the channel unit **4** in one-to-one correspondence with the upper ink supply channels **3***d* as shown in FIG. **4**. A manifold (common ink chamber) **5** is also formed in the channel unit **4** as shown in FIG. **4**. The lower ink supply channels **5***d* are in fluid communication with the manifold **5**.

As shown in FIG. **1**, FIG. **3**, and FIG. **10**, a plurality of (four, in this embodiment) rectangular cutouts or recesses **53** are formed on the reservoir unit **71** in the thickness direction of the reservoir unit **71**. The rectangular cutouts **53** are formed two on each side of the reservoir unit **71** with respect to the sub-scanning direction so that the rectangular cutouts **53** on opposing sides are staggered with respect to each other.

As shown in FIGS. **2**, **3**, and **10**, the space **85** is in fluid communication with the rectangular cutouts **53**. Each FPC **50** extends from the corresponding actuator unit **21**, passes through the space **85**, and passes through the corresponding rectangular cutout **53**. As shown in FIGS. **1**, **4**, and **10**, except for the rectangular cutouts **53**, the reservoir unit **71** has essentially the same shape and dimensions in plan as the channel unit **4**.

The controller **72** functions to control driving of the inkjet head **1**. As shown in FIG. **1** and FIG. **2**, the controller **72** includes: a main circuit board **72***a*; a plurality of (four, in this embodiment) sub-circuit boards **81**; and a plurality of (four, in this embodiment) driver ICs **80**.

The main circuit board **72***a* has a rectangular shape extending in the main scanning direction and is fixed on the reservoir unit **71** such that the surfaces opposing the sub-circuit boards **81** are perpendicular to the top surface of the reservoir unit **71**. The sub-circuit boards **81** are disposed in parallel to the surfaces of the main circuit board **72**_a_ and are electrically connected to the main circuit board **72**_a_ via connectors **73**.

Each driver IC **80** functions to generate signals for driving a corresponding actuator unit **21**. Each driver IC **80** is provided with a heat sink **82**. Each driver IC **80** is fixedly mounted on a corresponding sub-circuit board **81** on its side that confronts the main circuit board **72**_a_.

Each FPC **50** is electrically connected to both of a corresponding sub-circuit board **81** and a corresponding driver IC **80**. Each FPC **50** is fixed to the sub-circuit boards **81** via adhesive **83**. Each FPC **50** is for transferring signals outputted from the sub-circuit board **81** to the driver IC **80**, and for transferring drive signals outputted from the driver IC **80** to the corresponding actuator unit **21**.

As shown in FIG. **3**, each FPC **50** is bent and fixed by an adhesive **55** to the channel unit **4** at a location near an escape groove **54**, so that the FPC **50** does not come off of the corresponding actuator unit **21** when pulled upward.

As shown in FIGS. **1** and **2**, the lower cover **51** is a substantially rectangular-shaped hollow case and has openings in the bottom and top thereof. The lower case **51** has essentially the same dimension in the sub-scanning direction in plan with the main head member **70** (reservoir unit **71** and channel unit **4**). In other words, the cross-section of the lower case **51** along a plane parallel to the top and bottom surfaces of the main head member **70** has the same dimension in the sub-scanning direction with the main head member **70**. As shown in FIG. **1**, the lower cover **51** has a bottom edge **51**_b_. A plurality of (four, in this embodiment) protruding parts **51**_a_ protrude downwardly from the bottom edge **51**_b_. The lower cover **51** is disposed on top of the main head body **70**. The bottom edge **51**_b_ is located on the top surface of the reservoir unit **71**, while each protruding part **51**_a_ is accommodated in a corresponding rectangular cutout **53** of the reservoir unit **71**. As shown in FIG. **2**, each FPC **50** runs through a gap defined in the corresponding rectangular cutout **53**, and is drawn from the top of the reservoir unit **71**. The lower cover **51** covers the outer sides of portions of the FPCs **50** that extend along the rectangular cutouts **53** of the reservoir unit **71**.

As shown in FIG. **1**, FIG. **2**, and FIG. **3**, each FPC **50** is accommodated in the lower cover **51** to extend loosely over the corresponding actuator unit **21** so as not to be applied with any stress. The bottom edge **51**_b_ of the lower cover **51** is positioned on the upper edge of the reservoir unit **71**, while the protruding parts **51**_a_ are positioned above the upper edge of the channel unit **4**.

As shown in FIG. **3**, gaps e are formed between the protruding parts **51**_a_ and the edge on the upper surface of the channel unit **4** for absorbing error in manufacturing the lower cover **51**. After the lower cover **51** has been mounted, the gaps e are filled with a silicone resin or the like to prevent ink from flowing out through the gaps e. The escape grooves **54** are formed in the channel unit **4** at positions opposing the rectangular cutouts **53** for allowing excess silicone to escape when filling the gaps e with silicone resin. As shown in FIGS. **1** and **2**, the lower cover **51** further has a horizontal part **51**_d_, which surrounds the upper opening. The horizontal part **51**_d_ is formed by bending the upper edges of the side wall of the lower cover **51** inward along the horizontal. The FPCs **50** are led through the top opening of the lower cover **51** that is surrounded by the planar part **51**_d_.

As shown in FIG. **2**, the upper cover **52** is a casing with an arch-shaped ceiling, and is disposed on top of the horizontal parts **51**_d_ of the lower cover **51** for covering the main circuit board **72**_a_ and the sub-circuit boards **81**. When properly positioned, the lower cover **51** and upper cover **52** have a width in the sub-scanning direction that falls within the width of the main head member **70** in the sub-scanning direction.

Next, the structure of the main head member **70** will be described.

FIG. **4** is a plan view showing the main head member **70** of FIG. **1**. FIG. **5** is an enlarged plan view showing the region in FIG. **4** surrounded by a one-dot-and-one-chain line. It is noted that for purposes of description, pressure chambers **10** (pressure chamber groups **9**), apertures **12**, and nozzles **8** (which will be described later) are depicted with solid lines in FIG. **5**, although they are beneath the actuator units **21** and should be depicted in dotted lines. FIG. **6**(_a_) is a cross-sectional view taken along a line VI—VI in FIG. **5**. FIG. **6**(_b_) is a plan view of an aperture **12** shown in FIG. **6**(_a_). FIG. **7** is an exploded perspective view showing a part of the main head member **70**. FIG. **8**(_a_) is an enlarged cross-sectional view of a part surrounded by a broken line in FIG. **6**(_a_). FIG. **8**(_b_) is a plan view showing the shape of an individual electrode **35** shown in FIG. **8**(_a_).

As shown in FIGS. **4** and **5**, the main head member **70** includes the channel unit **4**. A plurality of (four, in this embodiment) actuator units **21** are bonded to the top surface of the channel unit **4**. The actuator units **21** are disposed in a staggered arrangement of two rows on the top surface of the channel unit **4**. Each actuator unit **21** has a trapezoidal-shape cross-section along a plane parallel to the top and bottom surfaces of the actuator unit **21**. Each trapezoidal-shaped actuator unit **21** is positioned with its parallel sides (top and bottom sides of the trapezoid) aligned with the longitudinal direction (main scanning direction) of the channel unit **4**. The trapezoidal-shaped actuator units **21** are arranged on the top surface of the channel unit **4** so that the slanted sides (slanted sides of the trapezoids) of each two neighboring actuator units **21** confront with each other with a gap being formed therebetween.

A plurality of (four, in this embodiment) ink ejection regions **11** (FIG. **5**) are defined on the bottom surface of the channel unit **4** in one-to-one correspondence with a plurality of (four, in this embodiment) regions of the top surface of the channel unit **4**, on which the plurality of (four, in this embodiment) actuator units **21** are bonded.

As shown in FIG. **5**, numerous nozzles **8** are formed on the bottom surface of the channel unit **4** in each ink ejection region **11**. The nozzles **8** are arranged in a matrix form in the ink ejection region **11**. Numerous pressure chambers **10**, each of which is in fluid communication with a single nozzle **8**, are formed on the top surface of the channel unit **4** and are arranged also in a matrix. A single pressure chamber group **9** is configured of a plurality of the pressure chambers **10** that are disposed on the top surface of the channel unit **4** in correspondence with the area in which a single actuator unit **21** is bonded. In this way, the numerous pressure chambers **10** are grouped into a plurality of (four, in this embodiment) pressure chamber groups **9**. Each pressure chamber **10** has a substantially diamond-shaped cross-section along a plane parallel to the top and bottom surfaces of the chamber unit **4**.

As shown in FIG. **4**, a manifold **5** is formed inside the channel unit **4**. The manifold **5** is configured from a plurality of sub-manifolds **5**_a_. A plurality of (ten, in this embodiment) openings **5**_b_ are formed in the top surface of the channel unit **4** in fluid communication with the manifold **5**. More specifically, a lower ink supply channel **5**_d_ extends from each opening **5**_b_ to corresponding sub-manifolds **5**_a_.

As will be described with reference to FIG. **9**(*a*) and FIG. **10**, each opening **5***b* is joined with a corresponding upper ink supply channel **3***d*, which is opened on the bottom surface of the reservoir unit **71**. Ink in the reservoir unit **71** is therefore supplied through the upper ink supply channels **3***d* to the lower ink supply channels **5***d*, and then to the sub-manifolds **5***a*.

As shown in FIG. **6**(*a*), each nozzle **8** grows narrower toward its tip end. Each nozzle **8** is in fluid communication with a sub-manifold **5***a* via a corresponding pressure chamber **10** and a corresponding aperture **12**. The sub-manifold **5***a* is a branch channel of the manifold **5**.

Next, the cross-sectional structure of the main head member **70** will be described.

As shown in FIG. **6**(*a*), each nozzle **8** is in fluid communication with a corresponding sub-manifold **5***a* via a corresponding pressure chamber **10** and a corresponding aperture **12**. Accordingly, an individual ink channel **32** is formed in the main head member **70** for each pressure chamber **10** and extends from the outlet of the sub-manifold **5***a* to the nozzle **8** via the aperture **12** and the pressure chamber **10**.

As shown in FIG. **7**, the main head member **70** has a laminated structure that includes a total of ten stacked sheets. From top to bottom, these sheets include the actuator unit **21**, a cavity plate **22**, a base plate **23**, an aperture plate **24**, a supply plate **25**, manifold plates **26**, **27**, and **28**, a cover plate **29**, and a nozzle plate **30**. The channel unit **4** is configured of nine of these metal plates, excluding the actuator unit **21**. These nine metal plates are formed of the same metal materials of stainless steel SUS316.

As will be described in detail later with reference to FIG. **8**(*a*), the actuator unit **21** includes four laminated piezoelectric sheets **41**–**44**, of which only the topmost sheet **41** has active layer portions (hereinafter referred to as the "active layer") when an electric field is generated by electrodes, while the remaining three sheets **42**–**43** are inactive layers.

The cavity plate **22** is a metal plate provided with a plurality of substantially diamond-shaped openings (through-holes) defining the pressure chambers **10**.

The base plate **23** is a metal plate. For each pressure chamber **10** in the cavity plate **22**, the base plate **23** is formed with a communication through-hole connecting the pressure chamber **10** to a corresponding aperture **12** and another communication through-hole connecting the pressure chamber **10** to a corresponding nozzle **8**.

The aperture plate **24** is a metal plate. For each pressure chamber **10** in the cavity plate **22**, the aperture plate **24** is formed with a communication through-hole connecting the pressure chamber **10** to the nozzle **8**. The aperture plate **24** is further formed with the aperture **12** for each pressure chamber **10** in the cavity plate **22**. The aperture **12** penetrates through the aperture plate **24**. As shown in FIG. **6**(*b*), the aperture **12** has an elongated shape and includes: one circular-shaped end **12***a* that is in communication with the pressure chamber **10**; the other circular-shaped end **12***b* that is in communication with the sub-manifold **5***a*; and a connecting section **12***c* that connects the circular-shaped ends **12***a* and **12***b* with each other. Each of the circular shaped ends **12***a* and **12***b* and the connecting section **12***c* penetrate through the aperture plate **24**. Each of the circular-shaped ends **12***a* and **12***b* has a circular cross-section along a plane parallel to the top and bottom surfaces of the aperture plate **24**. The connecting section **12***c* has an elongated cross-section along a plane parallel to the top and bottom surfaces of the aperture plate **24**, and has a width smaller than the diameters of the cross-section of the circular-shaped ends **12***a* and **12***b*. The aperture **12** is formed in the aperture plate **24** through an etching.

The supply plate **25** is a metal plate. For each pressure chamber **10** in the cavity plate **22**, the supply plate **25** is provided with a communication through-hole connecting the aperture **12** and the sub-manifold **5***a* and a communication through-hole connecting the pressure chamber **10** with the nozzle **8**.

The manifold plates **26**, **27**, and **28** are each provided with a through-hole for configuring the sub-manifold **5***a* when the plates are laminated together. For each pressure chamber **10** in the cavity plate **22**, each plate **26**, **27**, and **28** is further formed with a communication through-hole connecting the pressure chamber **10** to the nozzle **8**.

The cover plate **29** is a metal plate. For each pressure chamber **10** in the cavity plate **22**, the cover plate **29** is provided with a communication through-hole connecting the pressure chamber **10** to the nozzle **8**.

The nozzle plate **30** is a metal plate provided with the nozzle **8** for each pressure chamber **10** in the cavity plate **22**.

These nine metal plates **22**–**30** are aligned and stacked together to form the ink channel **32** as shown in FIG. **6**(*a*). The ink channel **32** begins from the sub-manifold **5***a* proceeding upward, extends horizontally in the aperture **12** before again proceeding upward, again extends horizontally in the pressure chamber **10**, and then proceeds downward to the nozzle **8**, first at a slant away from the aperture **12** and then straight downward.

Next, the structure of the actuator unit **21** will be described. The actuator unit **21** is stacked on the cavity plate **22**, which is the topmost layer of the channel unit **4**.

As shown in FIG. **8**(*a*), the actuator unit **21** includes the four piezoelectric sheets **41**–**44**, each having the same thickness of approximately 15 μm. These piezoelectric sheets **41**–**44** are continuous laminated plates (continuous planar layers) that span the plurality of pressure chambers **10** formed in a single ink ejection region **11** of the main head member **70** (FIG. **4** and FIG. **5**). By disposing the piezoelectric sheets **41**–**44** as continuous planar layers over the plurality of pressure chambers **10**, individual electrodes **35** can be densely arranged on the piezoelectric sheet **41** using a screen printing technique or the like. Therefore, the pressure chambers **10** can also be densely arranged at positions corresponding to the individual electrodes **35**, enabling the printing of high-resolution images. The piezoelectric sheets **41**–**44** are formed of ferroelectric ceramics such as lead zirconate titanate (PZT).

The individual electrodes **35** are formed on top of the piezoelectric sheet **41**, the topmost layer. The individual electrodes **35** are bonded to the top surface of the piezoelectric sheet **41**. A common electrode **34** formed as a sheet with a uniform thickness of approximately 2 μm is interposed between the piezoelectric sheets **41** and **42**. Electrodes are not provided between the piezoelectric sheets **42** and **43** and between the piezoelectric sheets **43** and **44**. Both the individual electrodes **35** and the common electrode **34** are formed of a metal material such as Ag—Pd.

Each of the individual electrodes **35** is planar with a thickness of approximately 1 μm and is substantially diamond-shaped, as shown in FIG. **8**(*b*), similar to the pressure chambers **10** shown in FIG. **5**. A circular land **36** having a diameter of approximately 160 μm protrudes upwardly from one acute angle end of the individual electrode **35**. The circular land **36** is electrically connected to the individual electrode **35**. The land **36** is formed of gold including glass frit, for example. As shown in FIG. **8**(*a*), the land **36** is bonded to the surface of an extended part of the individual electrode **35**. The land **36** is electrically joined to a contact provided on the FPC **50**.

The common electrode **34** is electrically grounded in an area not shown in the drawing, enabling the common electrode **34** to be maintained equally at a ground potential for all areas corresponding to the pressure chambers **10**. Further, the individual electrodes **35** are connected to the driver ICs **80** via the lands **36** and the FPCs **50**, which include a plurality of independent lead wires for the plurality of individual electrodes **35** in order to independently control the potential of the individual electrodes **35** corresponding to the plurality of pressure chambers **10**.

Next, a method of driving the actuator unit **21** will be described. The polarizing direction of the piezoelectric sheet **41** is equal to the direction of its thickness. Specifically, the actuator unit **21** has a unimorph structure in which the single piezoelectric sheet **41** on the top side (separated from the pressure chamber **10**) serves as active layers, while the three piezoelectric sheets **42**–**44** on the bottom side (near the pressure chamber **10**) are inactive layers. Accordingly, when a prescribed positive or negative potential is applied to individual electrodes **35** and if the directions of the electric field and polarization are the same, for example, areas of the piezoelectric sheet **41**, which are interposed between the electrodes **35** and the common electrode **34** and at which an electric field is applied, function as active layers and compress in a direction orthogonal to the polarizing direction due to the transverse piezoelectric effect. The piezoelectric sheets **42**–**44** are not affected by the electric field and therefore do not spontaneously compress. Accordingly, a difference in strain between the piezoelectric sheet **41** and the piezoelectric sheets **42**–**44** is produced in the direction orthogonal to the polarizing direction, causing all of the piezoelectric sheets **41**–**44** to deform in a convex shape on the inactive side (unimorph deformation).

As shown in FIG. **8**(*a*), since the bottom surface of the actuator unit **21** is fixed to the top surface of the cavity plate **22**, which serves to partition the pressure chambers **10**, the piezoelectric sheets **41**–**44** effectively deform in a convex shape toward the pressure chamber **10** side. As a result, the volumes of the pressure chambers **10** decrease, increasing the pressure of the ink and causing ink to eject from the nozzles **8**. When the individual electrodes **35** are subsequently returned to the same potential as the common electrode **34**, the piezoelectric sheets **41**–**44** return to their original shape and the pressure chambers **10** return to their original volumes, drawing ink in from the manifold **5** side.

Next, the structure of the reservoir unit **71** will be described in greater detail.

FIG. **9**(*a*) and FIG. **9**(*b*) are cross-sectional views of the reservoir unit **71** taken along a line IX—IX in FIG. **1**. FIG. **9**(*a*) is a cross-sectional view of the entire reservoir unit **71**, while FIG. **9**(*b*) is an enlarged cross-sectional view showing the region in FIG. **9**(*a*) surrounded by a broken line having alternate long and double short dashes. FIG. **10** is an exploded view of the reservoir unit **71**, with plan views of each plate constituting the reservoir unit **71**. In FIG. **9**(*a*) and FIG. **9**(*b*), the scale of the drawings is exaggerated vertically for purposes of description.

As shown in FIG. **9**(*a*), the reservoir unit **71** has a laminated structure including first through seventh plates **91**–**97**. The plates **91**–**97** are rectangular in shape extending in the main scanning direction and are formed of the same metal materials of the metal plates **22**–**30** in the channel unit **4** described above.

When aligned and laminated, the plates **91**–**97** form the ink downflow channel **3***b*, the ink reservoir **3***c*, and the upper ink supply channels **3***d* in the reservoir unit **71**. The ink inlet **3***a* is provided as an opening on the upstream side of the ink downflow channel **3***b*, while the downflow opening **63** is provided as another opening on the downstream side of the ink downflow channel **3***b*. The ink inlet **3***a* is positioned at the edge on the top surface of the reservoir unit **71**, while the downflow opening **63** confronts the center of the ink reservoir **3***c*.

The ink reservoir **3***c* is in fluid communication with the ink downflow channel **3***b* via the downflow opening **63**. The ink reservoir **3***c* is also in fluid communication with the ten upper ink supply channels **3***d*. Five upper ink supply channels **3***d* are arranged along the main scanning direction on each widthwise side of the reservoir unit **71**. Since FIG. **9**(*a*) is a cross-sectional view, only the five upper ink supply channels **3***d* and the five lower ink supply channels **5***d* formed on one widthwise side of the reservoir unit **71** are shown.

Next, each of the plates in the reservoir unit **71** will be described with reference to FIG. **10**.

A total of four rectangular notches **53***a* are formed in both edges of the first plate **91** in the sub-scanning direction (a direction normal to the surface of FIG. **9**(*a*)) with the two notches **53***a* in one edge staggered from the two notches **53***a* in the other edge in the main scanning direction. A circular through-hole **45** is formed in one end of the plate **91** with respect to the main scanning direction and near the center in the sub-scanning direction. The opening in the top of the through-hole **45** constitutes the ink inlet **3***a*.

A total of four rectangular notches **53***b* are formed in both edges of the second plate **92** with respect to the sub-scanning direction such that the two notches **53***b* in one edge are staggered from the two notches **53***b* in the other edge in the main scanning direction. As shown in FIG. **9**(*a*), an elongated through-hole **46** is formed in the second plate **92** penetrating the same in the thickness direction and extends parallel to the main scanning direction from a position opposing the through-hole **45** to the center of the second plate **92** in the main scanning direction.

The third plate **93** (filter plate) is formed with no notches **53***a* or **53***b*, but has a width in the sub-scanning direction identical to the width of the first and second plates **91** and **92** in the sub-scanning direction between notches **53***a* and **53***b*, respectively. In other words, the third plate **93** has a width smaller than the width of the first plate **91** by an amount equal to twice the amount of the notch **53***a*. In other words, the third plate **93** has a width smaller than the width of the second plate **92** by an amount equal to twice the amount of the notch **53***b*. In this example, the third plate **93** has a width of about 22 mm in the sub-scanning direction, and a length of about 180 mm in the main scanning direction. The third plate **93** has a thickness of about 50 μm in this example.

As shown in FIG. **9**(*b*) and FIG. **10**, a recess **65** is formed in the third plate **93**. A part of the plate **93**, on which the recess **65** is formed, will be referred to as "bottom wall portion **65***b*" of the recess **65** hereinafter, and a remaining part of the plate **93**, which is other than the bottom wall portion **65** and which surrounds the recess **65** in the main scanning direction and in the sub-scanning direction, will be referred to as "peripheral wall portion **65***c*". The top surface of the peripheral wall portion **65***c* is attached to the second plate **92**, while the bottom surface of the peripheral wall portion **65***c* is attached to the fourth plate **94**. The bottom surface of the bottom wall portion **65***b* is on the same plane with the bottom surface of the peripheral wall portion **65***c*.

The top surface of the bottom wall portion **65***b* is shifted in the thickness direction of the third plate **93** from the top surface of the peripheral wall portion **65***c* by an amount of the depth of the recess **65**. In other words, the thickness of the bottom wall portion **65***b* is less than the thickness of the peripheral wall portion **65***c*, that is, the thickness of the third plate **93**. In this example, the depth of the recess **65** is about 47 μm. In other words, the thickness of the bottom wall portion **65***b* is about 3 μm.

The recess **65** extends parallel to the main scanning direction from the center of the plate **93** toward the end corresponding to the through-hole **45**. The recess **65** has a width of about 10 mm in the sub-scanning direction, and a length of about 42 mm in the main scanning direction. In other words, the bottom wall portion **65***b* extends parallel to the main scanning direction from the center of the plate **93** toward the end corresponding to the through-hole **45**. The bottom wall portion **65***b* has a width of about 10 mm in the sub-scanning direction, and a length of about 42 mm in the main scanning direction.

A partitioning wall **65***a* is disposed in the center of the recess **65** and extends in the sub-scanning direction. The partitioning wall **65***a* protrudes upwardly in the thickness direction of the plate **93** from the bottom wall portion **65***b*. The partitioning wall **65***a* is connected to a pair of opposite sides of the peripheral wall portion **65***c*, which confront with each other in the sub-scanning direction. The partitioning wall **65***a* divides the recess **65** in two compartments. More specifically, the partitioning wall **65***a* partitions the bottom wall portion **65***b* into an upstream region **65***u* and a downstream region **65***d* with respect to a direction A, in which ink flows in the elongated through-hole **46** in the second plate **92** (upper ink downflow channel **64***a*) as will be described later.

The height of the partitioning wall **65***a* in the thickness direction of the plate **93** is substantially the same as the height of the peripheral wall portion **65***c*. In other words, the top surface of the partitioning wall **65***a* is on the same plane with the top surface of the peripheral wall portion **65***c*. Accordingly, the partitioning wall **65***a* can reinforce the bottom wall portion **65***b* and suppress weakening of the plate **93**, thereby preventing damage to the filter **67**.

The shape of the partitioning wall **65***a* in plan is not limited to that shown in FIG. **10**, but may be formed in other various shapes, such as a lattice shape, if the region of the recess **65** can be made appropriately large. Further, by connecting one or both ends of the partitioning wall **65***a* to the peripheral wall portion **65***c*, the reinforcing effect of the partitioning wall **65***a* on the filter **67** is further enhanced.

A plurality of through-holes **66** is formed in rows in the main scanning direction in the bottom wall portion **65***b*. In other words, the through-holes **66** are arranged in the main scanning direction. The bottom wall portion **65***c*, which is located on a bottom of the recess **65** and which is formed with the through-holes **66**, constitutes a filter **67**. By providing a large recess **65** elongated in the main scanning direction in this way, the size of the filter **67** is large, and numerous through-holes **66** can be formed in the bottom of the recess **65**, thereby reducing the channel resistance on ink passing through the filter **67**.

It is noted that the through-holes **66** are formed in both of the upstream region **65***u* and the downstream region **65***d*. That is, at least one through-hole **66** is formed in each of the upstream region **65***u* and the downstream region **65***d*. In this embodiment, the total number of the through-holes **66** formed in the upstream region **65***u* is the same as that of the through-holes **66** formed in the downstream region **65***d*.

As shown in FIG. **9**(*b*), each through-hole **66** has a circular cross-section along a plane parallel to the top and bottom surfaces of the third plate **93**. Each through-hole **66** is formed such that the surface area in the opening on the upstream end of the through-hole **66** with respect to a direction B, in which ink flows through the filter **67**, is smaller than that in the opening on the downstream end. In this example, the surface area in the opening on the upstream end of the through-holes **66** has a diameter of about 11 μm, while the surface area in the opening on the downstream end has a diameter of about 13 μm. It is noted that each nozzle **8** has a diameter of about 20 μm. By forming the opening in the downstream end of the through-hole **66** with a large surface area, the filtering effect of the through-hole **66** is the same as when the opening on the downstream end is formed smaller than that on the upstream end, but the flow resistance on ink passing through the through-hole **66** can be decreased. In other words, if the opening on the downstream end, or outlet, of the through-holes **66** is formed smaller than the opening on the upstream end, or inlet, ink can easily flow into the through-holes **66** but cannot easily flow out, thereby raising the flow resistance in the through-holes **66**. However, since the opening on the upstream end is made smaller than the opening on the downstream end in the present embodiment, ink flowing into the through-hole **66** through the opening on the upstream end can easily flow out through the opening on the downstream end, thereby reducing flow resistance.

A total of four rectangular notches **53***c* are formed in the side edges of the fourth plate **94** with respect to the sub-scanning direction, wherein two of the notches **53***c* formed in one edge are staggered from the two formed in the other edge in the main scanning direction. As shown in FIG. **9**(*a*) and FIG. **9**(*b*), a through-hole **68** is formed in the plate **94** at a position opposing the filter **67** and penetrates the plate **94** in the thickness direction. As shown in FIG. **10**, the through-hole **68** is elongated in the main scanning direction.

A total of four rectangular notches **53***d* are formed in the side edges of the fifth plate **95** with respect to the sub-scanning direction, wherein two of the notches **53***d* formed in one edge are staggered from the two formed in the other edge in the main scanning direction. A circular through-hole **69** is formed in the center of the fifth plate **95** with respect to both the main scanning direction and the sub-scanning direction. The opening on the downstream end of the through-hole **69** constitutes the downflow opening **63**.

A total of four rectangular notches **53***e* are formed in the side edges of the sixth plate **96** with respect to the sub-scanning direction, wherein two of the notches **53***e* formed in one edge are staggered from the two formed in the other edge in the main scanning direction. A through-hole **31** is formed in the center of the plate **96** with respect to both the main scanning direction and the sub-scanning direction. The through-hole **31** constitutes the ink reservoir **3***c*. The ink reservoir **3***c* includes a main channel **37** and eight subsidiary channels **38**. The main channel **37** extends in the main scanning direction and tapers from the center of the ink reservoir **3***c* toward two tip ends **3***ce*, which are located near both ends of the plate **96** in the main scanning direction. The eight subsidiary channels **38** branch off the main channel **37** and taper toward eight tip ends **3***ce*, which are located on both sides of the plate **96** in the sub-scanning direction. In this way, the ink reservoir **3***c* has a plurality of (ten, in this embodiment) tip ends **3***ce* at points corresponding to through-holes **33**, which are formed in the seventh plate **97** to constitute the plurality of (ten, in this embodiment) upper ink supply channels **3***d* as will be described later.

A total of four rectangular notches **53f** are formed in the side edges of the seventh plate **97** with respect to the sub-scanning direction, wherein two of the notches **53f** formed in one edge are staggered from the two formed in the other edge in the main scanning direction.

The ten through-holes **33** are formed in the plate **97**. Each through-hole **33** constitutes the upper ink supply channel **3d**. Each through-hole **33** has a substantially circular cross-section along a plane parallel to the top and bottom surfaces of the seventh plate **87**. Five through-holes **33** are formed on each side of the plate **97** with respect to the sub-scanning direction, and are arranged along the main scanning direction. Further, the through-holes **33** formed in opposing sides of the plate **97** with respect to the sub-scanning direction are staggered in the main scanning direction by two units of two through-holes **33** and one unit of one through-hole **33** that is near an end of the plate **97** in the main scanning direction. The through-holes **33** are arranged symmetrically about a center point of the plate **97** with respect to the main scanning direction and the sub-scanning direction.

A recess **39** is formed by half etching in the surface of the plate **97** opposing the channel unit **4**. The outline of the recess **39** is indicated by broken lines in FIG. **10**. The recess **39** is opened at the both edges of the plate **97** in the sub-scanning direction at the notches **53f**. The recess **39** forms the space **85** described above when the plate **97** is stacked on the top surface of the channel unit **4**, as shown in FIG. **9**(*a*).

When aligned, the notches **53a**–**53f** formed in the first, second, and fourth through seventh plates **91**, **92**, and **94**–**97** constitute the four rectangular cutouts **53** for leading out the four FPCs **50**, which are connected to the four actuator units **21**.

When a thermosetting adhesive is applied between each of the first through seventh plates **91**–**97** and the plates are bonded together by applying heat and pressure, the reservoir unit **71** configured of the plates **91**–**97** does not warp in a direction perpendicular to the top surface or bottom surface thereof, because the plates **91**–**97** are formed of the same metal materials. In other words, because the plates **91**–**97** are formed of the same metal materials, the linear expansion coefficients of the plates are equal to one another and hence each of the plates expands equally within the plane parallel to the top and bottom surfaces thereof when heat and pressure are applied. Accordingly, the reservoir unit **71** configured by joining the plates **91**–**97** with heat and pressure does not warp. Even if the third plate **93** shown in FIG. **9**(*a*) is formed of a different material than the other plates **91**, **92**, and **94**–**97** and therefore planar expansion of the plate **93** is different from those of the other plates, since the plate **93** is interposed between the second and fourth plates **92** and **94**, the reservoir unit **71** configured of the plates **91**–**97** exhibits almost no warp when the plates **91**–**97** are bonded by heat and pressure. It is noted, however, that when the plate **93** is formed of a different material than the other plates **91**, **92**, and **94**–**97**, it is desirable to select, for the plate **93**, a material whose linear expansion coefficient is similar to the linear expansion coefficients of the other plates **91**, **92**, and **94**–**97** as much as possible to deter warping in the reservoir unit **71**. In the present embodiment, both the channel unit **4** and the reservoir unit **71** are configured of metal plates to improve the durability of the inkjet head **1**.

Next, the ink channels in the reservoir unit **71** will be described.

Ink supplied from an ink tank (not shown) into the ink downflow channel **3b** via the ink inlet **3a** flows down into the ink reservoir **3c** through the downflow opening **63**. The filter **67** is disposed in the ink downflow channel **3b** as described above. The ink inlet **3a** is formed on one end of the reservoir unit **71** in the main scanning direction. The downflow opening **63** (circular through-hole **69**) is formed at a position opposing the center region of the ink reservoir **3c** that includes the center location among the plurality of upper ink supply channels **3d**. The filter **67** divides the ink downflow channel **3b** into an upper ink downflow channel **64a** formed above the filter **67** as a channel upstream of the filter **67**, and a lower ink downflow channel **64b** formed below the filter **67** as a channel downstream of the filter **67**. As shown in FIG. **9**(*a*), the upper ink downflow channel **64a** is defined by a space provided by the through-hole **46**, while the lower ink downflow channel **64b** is defined by a space provided by the through-holes **68** and **69**. Hence, ink, which is supplied through the ink inlet **3a** provided on one end of the reservoir unit **71** in the main scanning direction, is guided through the ink downflow channel **3b** to flow into the downflow opening **63**, which is provided in the center of the reservoir unit **71** in the main scanning direction, thereby flowing into the center area of the ink reservoir **3c**.

Because the filter **67** is disposed in the ink downflow channel **3b**, the filter **67** has a large area and attains a small flow resistance on the ink being filtered. Specifically, since the cross-sectional area of the ink channel leading to the manifold **5** is greater than a microchannel such as the ink channel **32** in communication with the nozzle **8**, the filter **67** can be configured with a large surface area by being disposed in this ink channel.

The ink reservoir **3c** serves not only to store ink, but also to supply ink to the upper ink supply channels **3d**. The ink reservoir **3c** is in fluid communication with the upper ink supply channels **3d** at the ten tip ends **3ce**. These ten tip ends **3ce** are positioned in correspondence with the ten through-holes **33** constituting the upper ink supply channels **3d** formed in the plate **97** and are in fluid communication with the through-holes **33**. The ten tip ends **3ce** are arranged in two rows in the reservoir unit **71** along the main scanning direction, with five tip ends **3ce** located on each side of the reservoir unit **71** in the sub-scanning direction. The tip ends **3ce** on opposing sides are staggered in units of one formed near an end in the main scanning direction and the remainder in units of two. The ink reservoir **3c** has a cross-sectional shape, along a plane parallel to the top and bottom surfaces of the plate **96**, that is symmetrical about a center point of the plate **96** with respect to the main scanning direction, the center point being the point, at which ink flows from the downflow opening **63** into the ink reservoir **3c**.

The upper ink supply channels **3d** are in fluid communication with the ink reservoir **3c** on their upstream sides and are in fluid communication with the manifold **5** via the lower ink supply channels **5d** on their downstream sides. The upper ink supply channels **3d** receive ink from the ink reservoir **3c** and supply ink to the manifold **5**. The upper ink supply channels **3d** are formed in two rows along the main scanning direction, with five on each side of the reservoir unit **71** in the sub-scanning direction, and are located in one-to-one correspondence with the tip ends **3ce** of the ink reservoir **3c**. The upper ink supply channels **3d** on opposing sides of the reservoir unit **71** are staggered in units of two, except for one upper ink supply channel **3d** formed near both ends of the reservoir unit **71** in the main scanning direction. Hence, the upper ink supply channels **3d** are arranged symmetrically about a center point of the plate **97** with respect to the main scanning direction that corresponds to the point at which ink flows into the ink reservoir **3c** from the downflow opening **63**.

Next, the flow of ink in the reservoir unit **71** will be described.

Ink introduced into the ink inlet **3***a* of the reservoir unit **71** from an ink tank not shown in the drawings flows vertically (in the direction in which the plates **91**–**97** constituting the reservoir unit **71** are stacked) down into the ink downflow channel **3***b*. Ink that reaches the ink downflow channel **3***b* flows along the upper ink downflow channel **64***a* substantially in the main scanning direction and horizontally over the filter **67** (the direction along the planar surfaces of the plates **91**–**97**), while being filtered through the filter **67**. After passing through the filter **67**, by which foreign matter is removed from the ink, the ink forms a vertical flow following the lower ink downflow channel **64***b* and flows down through the downflow opening **63** into the center region of the ink reservoir **3***c*. From the center region of the ink reservoir **3***c*, the ink flows toward both tip ends of the main channel **37** in the main scanning direction. A portion of ink reaches the tips **3***ce* at the ends of the main channel **37**, and flows into the upper ink supply channels **3***d*. A remaining portion of the ink that flows through the main channel **37** flows into the plurality of sub-channels **38** branching off of the main channel **37**. Ink reaching the end of these sub-channels **38** flows into the upper ink supply channels **3***d*. Ink introduced into the upper ink supply channels **3***d* flows through the upper ink supply channels **3***d* into the lower ink supply channels **5***d* of the channel unit **4** and is supplied to the manifold **5**.

Next, a method of manufacturing the reservoir unit **71** will be described.

All of the plates **91**–**97** of the reservoir unit **71**, excluding the third plate **93**, are formed using an etching method well known in the art for producing the through-holes **31**, **33**, **45**, and **69** and the elongated through-holes **46** and **48** in the plates **91**, **92**, and **94**–**97** and a punching process for forming the notches **53***a*–**53***f* in the plates **91**, **92**, and **94**–**97**. As described above, the recess **39** is formed in the bottom surface of the seventh plate **97** by half etching.

The filter **67** is formed in the third plate of the reservoir unit **71** according to the steps shown in FIG. **11**(*a*)–FIG. **11**(*e*).

FIG. **11**(*a*) shows the plate material for the plate **93** prior to forming the filter **67**. FIG. **11**(*b*) shows the plate **93** after resist layers have been formed on the surfaces thereof. FIG. **11**(*c*) shows the plate **93** after holes that will become the through-holes **66** have been formed in the bottom surface of the plate **93** and the resist layers have been removed. FIG. **11**(*d*) shows the plate **93** after resist layers have again been formed over the surfaces of the plate **93**. FIG. **11**(*e*) shows the plate **93** after the recess **65** has been formed therein and the resist layers have been removed to complete formation of the filter **67**.

In order to form the filter **67** in the plate **93**, first, material for the plate **93** is prepared with no alterations, as shown in FIG. **11**(*a*).

Then, resist layers **101** (**101***a* and **10***b*) are formed on the top and bottom surfaces of the plate **93**, as shown in FIG. **11**(*b*). At this time, the resist layer **101***a* is formed over the entire top surface of the plate **93**, while the resist layer **101***b* is formed over the bottom surface of the plate **93**, excluding regions for forming the plurality of through-holes **66**. After forming the resist layers **101** in this way, the plate **93** is immersed in a chemical solution that etches away areas of the plate **93** not covered by the resist layers **101** until semicircular depressions **66***a* have been formed, as shown in FIG. **11**(*c*).

Subsequently, the resist layers **101** are removed from the plate **93**, as shown in FIG. **11**(*c*).

Next, other resist layers **102** are formed over the entire bottom surface of the plate **93** and over the top surface, excluding regions for forming the recess **65**, as shown in FIG. **11**(*d*). Hence, the top surface of the plate **93** is coated with the resist layer **102** so as to expose regions in which the plurality of depressions **66***a* have been formed and to cover all other areas (including the region in which the partitioning wall **65***a* is formed). After forming the resist layers **102**, the plate **93** is immersed in a chemical solution that is allowed to etch away depressions in the plate **93** at areas not covered by the resist layers **102** (regions indicated by dotted lines in FIG. **11**(*d*)) until the newly-created depressions reach the depressions **66***a*.

Subsequently, the resist layers **102** are removed from the plate **93**, as shown in FIG. **11**(*e*). In this way, it is possible to form in the plate **93** the plurality of through-holes **66**, the recess **65** in fluid communication with the through-holes **66**, and the partitioning wall **65***a*, thereby forming the filter **67** in the plate **93**.

Hence, when forming the filter **67** in the plate **93**, first, depressions **66***a* that will eventually become the through-holes **66** are formed in the bottom surface of the plate **93** by etching the bottom surface.

Next, the recess **65** and the partitioning wall **65***a* are formed by etching the top surface of the plate **93**, simultaneously forming the through-holes **66** by connecting the bottom surface of the recess **65** with the depressions **66***a*.

Since the through-holes **66** of the filter **67** are formed from the bottom surface side of the plate **93** through the isotropic etching of a chemical solution, the area of the opening on the bottom surface side of the through-holes **66** in the thickness direction of the plate **93** is greater than the area of the opening on the top surface side. Accordingly, by disposing the plate **93** so that the upper surface side is the upstream side of the ink channel, the flow resistance to ink passing through the through-holes **66** is reduced, as described above.

Further, by forming the plurality of through-holes **66** in the bottom surface of the recess **65**, it is possible to form through-holes **66** with small diameters and having a sufficient capacity for removing foreign matter, even when the plate **93** is relatively thick. Since the through-holes **66** can be formed with small diameters, a large number of the through-holes **66** can be formed densely within the region of the filter **67**. Therefore, it is possible to use a thick plate **93** to facilitate handling when stacking the plate **93** with the other plates **91**, **92**, and **94**–**97**, while also producing a filter **67** having numerous through-holes **66** with small diameters and an excellent filtering effect. This method also prevents an increase in flow resistance on ink passing through the filter **67** formed in the plate **93**.

Further, the cost of manufacturing the third plate **93** having the filter **67** formed by etching can be much less than manufacturing a filter plate formed of a synthetic resin plate in which a plurality of through-holes have been formed with an excimer laser. Hence, the inkjet head **1** having this filter **67** can be manufactured at a low cost.

With the inkjet head **1** according to the embodiment described above, the filter **67** formed in the plate **93** of the reservoir unit **71** is configured of the recess **65** and the plurality of through-holes **66** formed in the bottom of the recess **65**, enabling through-holes **66** with small diameters to be formed in a thick plate. Specifically, by providing the recess **65** in the plate **93**, the bottom portion of the recess **65** in which the through-holes **66** are formed can be made extremely thin, reducing the amount of etching in the planar direction of the plate **93** when forming the through-holes **66** by etching. As a result, the through-holes **66** can be formed with small diameters. Since a plurality of the through-holes **66** can be formed in the bottom of the recess **65**, the flow resistance on ink passing through the filter **67** is reduced. Further, since a filter **67** having sufficient filtering capacity can be provided in a thick plate, the strength of the plate **93** in which the filter **67** is formed is not degraded, improving the handling of the plate **93** when laminating plates to form the reservoir unit **71**.

While it is common to use a thinner plate for forming filter through-holes with a smaller diameter by etching, a thinner plate is not desirable when considering the handling strength of the plate. However, if a thicker plate is employed and etching is used to form through-holes from one surface side of the thick plate, the diameter of the through-holes grows in proportion to the thickness of the plate, because the etching proceeds isotropically.

Contrarily, according to the present embodiment, the filter **67** is formed in a thick plate with consideration for handling, and the through-holes **66** are formed in the bottom portion of the recess **65** formed in the plate. Therefore, a large number of small through-holes can be formed in the bottom of the recess, without being influenced by the thickness of the plate. Hence, the present embodiment can provide a plate that has the filter **67** having a sufficient filtering capacity and sufficient strength for handling, and that does not unduly increase flow resistance on the ink.

Next, an inkjet head according to a second embodiment of the present invention will be described.

FIG. **12**(*a*) and FIG. **12**(*b*) are cross-sectional views of the reservoir unit in an inkjet head according to the second embodiment, wherein FIG. **12**(*a*) is a cross-sectional view showing the entire reservoir unit, while FIG. **12**(*b*) is an enlarged cross-sectional view of the region in FIG. **12**(*a*) surrounded by a broken line with alternating long and double short dashes. For purposes of description, the vertical dimension of the reservoir unit in FIG. **12**(*a*) and FIG. **12**(*b*) is exaggerated. Parts and components similar to those of the inkjet head **1** according to the first embodiment described above are indicated by the same reference numerals to avoid duplicating description.

An inkjet head **201** according to the second embodiment includes a reservoir unit **271** shown in FIG. **12**(*a*). The reservoir unit **271** has the same construction as the reservoir unit **71** according to the first embodiment described above, except that a third plate **93'** is used instead of the third plate **93** of the first embodiment and that the third plate **93'** has a filter **267** instead of the filter **67** in the first embodiment.

The filter **267** includes: the bottom wall portion **65***b* defining the recess **65** thereon; a plurality of through-holes **266** and a plurality of through-holes **268**, both of which are formed in the bottom wall portion **65***b*; and the partitioning wall **65***a*. As shown in FIG. **12**(*b*), the partitioning wall **65***a* partitions the bottom wall portion **65***b* into the upstream region **65***u* and the downstream region **65***d* with respect to the direction A, in which ink flows in the upper ink downflow channel **64***a*. The through-holes **266** are formed in the upstream region **65***u*, while the through-holes **268** are formed in the downstream region **65***d*. The total number of the through-holes **266** is the same as that of the through-holes **268**. Each of the through-holes **266** and **268** is shaped similar to the through-hole **66** in the first embodiment. More specifically, the area of the opening of each through-hole **266** in the bottom surface side of the third plate **93'** is greater than the area of the opening of the through-hole **266** on the top surface side, and the area of the opening of each through-hole **267** in the bottom surface side of the third plate **93'** is greater than the area of the opening of the through-hole **267** on the top surface side. According to the present embodiment, however, each through-hole **266** is formed with a smaller diameter than each through-hole **268**. For example, the diameter of each through-holes **266** is smaller than that of the through-hole **268** by an amount of about 2 μm.

The method of forming the filter **267** in the third plate **93'** according to the present embodiment is substantially the same as the method of forming the filter **67** in the plate **93** according to the first embodiment. However, when forming the areas of the through-holes **266** and **268** by etching, the resist layer is formed on the third plate **93'** at regions corresponding to the through-holes **266** and **268** having different diameters. Hence, the resist layer is formed at different regions than the resist layer **101***b* in the first embodiment described above. Otherwise, the method of forming the filter **267** in the third plate **93'** is identical to the method of forming the filter **67** in the first embodiment.

In addition to the advantages obtained by the ink-jet head **1** according to the first embodiment described above, the inkjet head **201** according to the second embodiment obtains the following advantages.

By forming the diameter of the through-holes **268** in the filter **267** larger than that of the through-holes **266**, the through-holes **268** have less pressure loss than the through-holes **266**. For this reason, ink flowing through the through-holes **268** has less flow resistance, facilitating the flow of ink in the downstream region of the upper ink downflow channel **64***a* and preventing bubbles from accumulating in the ink in the area of the upper ink downflow channel **64***a* that confronts the through-holes **268**. More specifically, since the ink downflow channel **3***b* changes the ink flow from a horizontal direction A in the upper ink downflow channel **64***a* to a vertical direction B in the lower ink downflow channel **64***b*, the flow of ink tends to stagnate in a corner P shown in FIG. **12**(*a*) in the downstream region of the upper ink downflow channel **64***a*, and air bubbles in the ink tend to accumulate at this corner P. However, in the present embodiment, ink flows more freely through the through-holes **268** provided near the corner P in the downstream region of the upper ink downflow channel **64***a*, thereby preventing air bubbles from accumulating in the corner P.

In the inkjet head **1** of the first embodiment described above, the number of the through-holes **66** formed in the upstream region **65***u* is equal to the number of the through-holes **66** formed in the downstream region **65***d*, and all of the through-holes **66** have the same diameter. However, the number of through-holes **66** in the upstream region **65***u* may be made smaller than the number in the downstream region **65***d* in order to produce a differential in pressure loss between the upstream side and downstream side of the upper ink downflow channel **64***a*, thereby reducing the pressure loss of ink passing through the through-holes **66** formed in the downstream region **65***d*. Hence, the flow resistance on ink passing through the through-holes **66** formed in the downstream region **65***d* can be made less than the flow resistance on ink passing through through-holes **66** formed in the upstream region **65***u*, thereby facilitating the flow of ink through the downstream region of the upper ink downflow channel **64***a* so that air bubbles in the ink have less tendency to accumulate in the corner P of the downstream region.

While the invention has been described in detail with reference to the specific embodiments thereof, it would be apparent to those skilled in the art that various changes and modifications may be made therein without departing from the spirit of the invention.

For example, the filter may be formed in the individual ink channels in the channel unit **4**. For example, the filter may be formed at a location between the lower ink supply channel **5***d* and the sub-manifold **5***a*.

The partitioning wall **65***a* may be eliminated from the filter **67** and the filter **267**.

The openings in the top surface side of the through-holes **66** formed in the filter **67** may be larger than the openings in the downstream end. That is, when forming the filter **67**, the recess **65** may be formed first, and the through-holes **66** may be subsequently formed in the thin bottom portion of the recess **65** from the recess **65** side.

Further, in the preferred embodiments, the partitioning wall **65***a* is formed in the ink downflow channel **3***b* to extend in the sub-scanning direction (orthogonal to the direction A of ink flow), but may be formed to extend in the main scanning direction (the direction A of ink flow). This construction can produce a smooth flow of ink through the upper ink downflow channel **64***a*. In this case, it is desirable that the downstream end of the partitioning wall **65***a* be connected to the peripheral wall portion **65***c*. This construction serves not only as a structural reinforcement of the filter **67** or filter **267**, but also to guide air bubbles in the ink to the downstream side of the upper ink downflow channel **64***a*. Especially in a filter constructed like the filter **267** of the second embodiment to facilitate ink flow in the downstream region of the filter **267**, air bubbles in the ink can be easily discharged rather than being accumulated.

Further, the method for forming the filter **67** in the plate **93** is not limited to an etching method. The present invention may be applied to any method for forming filter through-holes by removing plate material isotropically from one surface side of the plate.

What is claimed is:

1. An inkjet head, comprising:

a plurality of laminated plates, the plates having holes that are arranged in communication with one another to form an ink channel,

at least one of the plurality of plates including a filter portion disposed in the ink channel, the filter portion including a bottom wall portion defining a depression thereon, a plurality of filter through-holes being formed through the bottom wall portion, wherein an area of an opening in each filter through-hole on an upstream side of the ink channel in an ink flowing direction through the filter portion is smaller than an area of another opening in the subject filter through-hole on a downstream side of the ink channel.

2. The inkjet head according to claim **1**, wherein the at least one plate includes a first surface and a second surface opposite to the first surface, the bottom wall portion including a first bottom surface and a second bottom surface opposite to the first bottom surface, the depression being located on the first bottom surface, a bottom thickness defined as a distance between the first bottom surface and the second bottom surface being smaller than a plate thickness defined as a distance between the first surface and the second surface.

3. The inkjet head according to claim **1**, wherein the at least one plate includes a peripheral wall portion, the depression being surrounded by the bottom wall portion and the peripheral wall portion, the peripheral wall portion having a first surface and a second surface opposite to the first surface, the bottom wall portion including a first bottom surface and a second bottom surface opposite to the first bottom surface, the depression being located on the first bottom surface, a bottom thickness defined as a distance between the first bottom surface and the second bottom surface being smaller than a plate thickness defined as a distance between the first surface and the second surface.

4. The inkjet head according to claim **3**, wherein the second surface is located on the same plane with the second bottom surface, and wherein the first bottom surface is shifted from the first surface by a depth of the depression, the depth of the depression being equal to a difference between the plate thickness and the bottom thickness.

5. The inkjet head according to claim **1**, wherein the plurality of plates include an ink-inlet plate formed with an ink inlet,

further comprising:

a nozzle plate formed with a plurality of nozzles; and another plurality of laminated plates formed with a common ink chamber that is in fluid communication with the ink channel and that is in fluid communication with the plurality of nozzles, the ink channel being configured so that ink supplied from an external source through the ink inlet flows through the common ink chamber toward the plurality of nozzles to be ejected.

6. The inkjet head according to claim **5**, wherein the filter portion is disposed in the ink channel between the ink inlet and the common ink chamber.

7. The inkjet head according to claim **6**, wherein the ink channel includes an ink reservoir that stores ink therein, the ink reservoir being disposed between the ink inlet and the common ink chamber; and

the filter portion is disposed in a reservoir channel defined between the ink inlet and the ink reservoir.

8. The inkjet head according to claim **7**, wherein the plurality of filter through-holes in the filter portion include:

an upstream-side filter through-hole; and

a downstream-side filter through-hole that is located in a downstream side of the upstream-side filter through-hole in the ink flowing direction along the reservoir channel,

the upstream-side filter through-hole having a smaller diameter than the downstream-side filter through-hole.

9. The inkjet head according to claim **1**, wherein the at least one plate is elongated in a predetermined direction, the depression being elongated in the predetermined direction, and the plurality of filter through-holes are arranged along the predetermined direction.

10. The inkjet head according to claim **1**, wherein the filter portion has a partitioning wall that divides the depression into a plurality of compartments, each compartment including at least one filter through-hole.

11. The inkjet head according to claim **10**, wherein both ends of the partitioning wall connect to peripheral wall portions of the depression, and the thickness of the plate is greater than the thickness of the bottom wall portion of the depression.

12. The inkjet head according to claim **1**, wherein each of the plurality of plates is a metal plate.

13. The inkjet head according to claim **1**, further comprising a channel unit in which a plurality of nozzles and a plurality of pressure chambers are formed,

wherein the plurality of laminated plates configure a reservoir unit fixed to the channel unit,

the reservoir unit including in the ink channel:

an ink inlet;

an ink reservoir;

a reservoir channel connecting the ink reservoir to the ink inlet, the filter portion being disposed in the reservoir channel; and

a plurality of first ink supply channels communicating outside of the reservoir unit with the ink reservoir,

the channel unit including:

a common ink chamber;

a plurality of individual ink channels extending from an outlet of the common ink chamber through the plurality of pressure chambers to the plurality of nozzles; and

a plurality of second ink supply channels in fluid communication with the corresponding first ink supply channels to connect the ink reservoir to the common ink chamber.

14. The inkjet head according to claim **13**, wherein the channel unit is configured of another plurality of laminated plates having holes for forming the nozzles, the pressure chambers, the common ink chamber, the individual ink channels, and the plurality of second ink supply channels, and wherein each plate in the channel unit is a metal plate and each plate in the reservoir unit is a metal plate.

15. The inkjet head according to claim **14**, wherein the plurality of filter through-holes are formed by etching one surface side of the metal plate, and the depression is formed by etching the opposite surface of the metal plate.

16. The inkjet head according to claim **15**, wherein the metal plate having the filter portion is formed of the same metal material as the other metal plates constituting the channel unit and the reservoir unit.

17. A filter plate for an inkjet head, the inkjet head including a plurality of laminated plates, the plurality of plates including the filter plate, the plurality of laminated plates having holes that are arranged to form an ink channel, the filter plate comprising:

a filter portion, which is disposed in the ink channel which is formed when the plurality of plates are laminated together, the filter portion including a bottom wall portion defining a depression thereon, a plurality of filter through-holes being formed through the bottom wall portion, wherein an area of an opening in each filter through-hole on an upstream side of the ink channel in an ink flowing direction through the filter portion is smaller than an area of another opening in the subject filter through-hole on a downstream side of the ink channel.

18. The filter plate according to claim **17**, further comprising a peripheral wall portion, the depression being surrounded by the bottom wall portion and the peripheral wall portion, the peripheral wall portion having a first surface and a second surface opposite to the first surface, the bottom wall portion including a first bottom surface and a second bottom surface opposite to the first bottom surface, the depression being located on the first bottom surface, a bottom thickness defined as a distance between the first bottom surface and the second bottom surface being smaller than a plate thickness defined as a distance between the first surface and the second surface,

the second surface being located on the same plane with the second bottom surface, and the first bottom surface being shifted from the first surface by a depth of the depression, the depth of the depression being equal to a difference between the plate thickness and the bottom thickness.

19. A method of manufacturing a filter plate serving as a component of an inkjet head including a plurality of laminated plates, the plates having holes that are arranged to form an ink channel, the filter plate having a filter portion that traps foreign matter in ink in the ink channel, the method comprising:

forming a plurality of holes within a predetermined region on one surface of a metal plate, the holes having a depth smaller than the thickness of the metal plate; and

forming filter through-holes penetrating the metal plate by etching a depression across the entire predetermined region on the opposite surface of the metal plate, the depression connecting the holes, thereby forming through-holes.

20. The method of manufacturing a filter plate according to claim **19**, wherein the hole forming step includes:

forming a resist layer on the one surface of the metal plate, while exposing hole forming regions desired to form the plurality of holes, and forming another resist layer over the entire surface of at least the predetermined region on the opposite surface of the metal plate;

forming the plurality of holes by etching the hole forming regions; and

removing the resist layers from the metal plate.

21. The method of manufacturing a filter plate according to claim **19**, wherein the depression forming step includes:

forming a resist layer over the entire surface of at least the predetermined region on the one surface of the metal plate and forming a resist layer on the opposite surface while exposing the predetermined region;

forming the depression by etching the predetermined region; and

removing the resist layers from the metal plate.

22. A filter plate for an inkjet head, the inkjet head including a plurality of laminated plates including the filter plate, the plurality of laminated plates having holes that are arranged to form an ink channel, the filter plate being formed with a depression that is to be located in the ink channel when the plurality of plates are laminated together, a plurality of filter through-holes being formed through a bottom portion of the depression, wherein an area of an opening in each filter through-hole on an upstream side of the ink channel in an ink flowing direction through the filter portion is smaller than an area of another opening in the subject filter through-hole on a downstream side of the ink channel.

23. An inkjet head, comprising:

a plurality of laminated plates, the plates having holes that are arranged in communication with one another to form an ink channel, at least one of the plurality of plates being formed with a depression at a location in the ink channel, a plurality of filter through-holes being formed through a bottom of the depression, wherein an area of an opening in each filter through-hole on an upstream side of the ink channel in an ink flowing direction through the filter portion is smaller than an area of another opening in the subject filter through-hole on a downstream side of the ink channel.

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